PILOT STUDY FOR QUANTIFYING LEED ENERGY & ATMOSPHERE OPERATIONAL SAVINGS IN HEALTHCARE FACILITIES

A Thesis

by

PATRICK RUDOLPH DANIELS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2012

Major Subject: Construction Management

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Approved by:

Chair of Committee,	Sarel Lavy
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	Kirk Hamilton
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ABSTRACT

Pilot Study for Quantifying LEED Energy & Atmosphere Operational Savings in Healthcare Facilities.

(August 2012)

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Chair of Advisory Committee: Dr. Sarel Lavy

Owner groups and Facility Managers of health care facilities interested in reducing operation and maintenance (O&M) expenses for new facilities have often been placed in the difficult position of making cost-benefit assessments without a complete understanding of the cumulative impact of building systems selection on their internal rate of return. This is particularly true when owners are evaluating the initial cost and operational benefit (if any) of obtaining various levels of “Leadership in Energy and Environmental Design” (LEED) certifications for their buildings.

Heating Ventilation and Air Conditioning, and Lighting (HVAC&L) loads comprise 51% of the total energy demand in the typical outpatient facility; however, in order to estimate the likelihood of achieving a particular LEED rating for a new building, a “Whole Building Energy Simulation” is necessary to evaluate HVAC&L system performance. The conventional of requiring a design upon which to base an analysis presents owner operators attempting to perform a Lifecycle Cost Analysis (LCCA) early in the concept phase with two unique problems - how to estimate energy use without an

actual “design” to model, and how to estimate a system’s first cost without knowing its performance requirements.

This study outlines a process by which existing energy metrics from the Department of Energy (DOE), Commercial Building Energy Consumption Survey (CBECS), and Energy Star, can be made early during the developer’s pro forma phase - without the need for a building design. Furthermore, preliminary business decisions targeted at determining the likelihood of obtaining a particular LEED rating, and specifying the corresponding building systems, can be estimated without the cost required to employ an Architect and Engineer (A&E) team, or the time necessary to develop a design.

This paper concludes that regional factors can dramatically affect a building’s required level of energy performance, and that the highest performing HVAC&L system, irrespective of cost, will not always provide the best return on investment. Accordingly, the national averages utilized to establish LEED EA1 thresholds do not reflect the cost particularities owners may encounter when developing in various climate zones, and therefor may be less relevant to lifecycle considerations that previously believed.

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CHAPTER I

INTRODUCTION

Regionally Adjusted Life Cycle Cost Assessments per LEED Rating Systems

Owner groups and Facility Managers of health care facilities interested in reducing operation and maintenance (O&M) expenses for new facilities have often been placed in the difficult position of making cost-benefit assessments without a complete understanding of the cumulative impact of building systems selection on their internal rate of return (Fuller and Petersen, 1995).

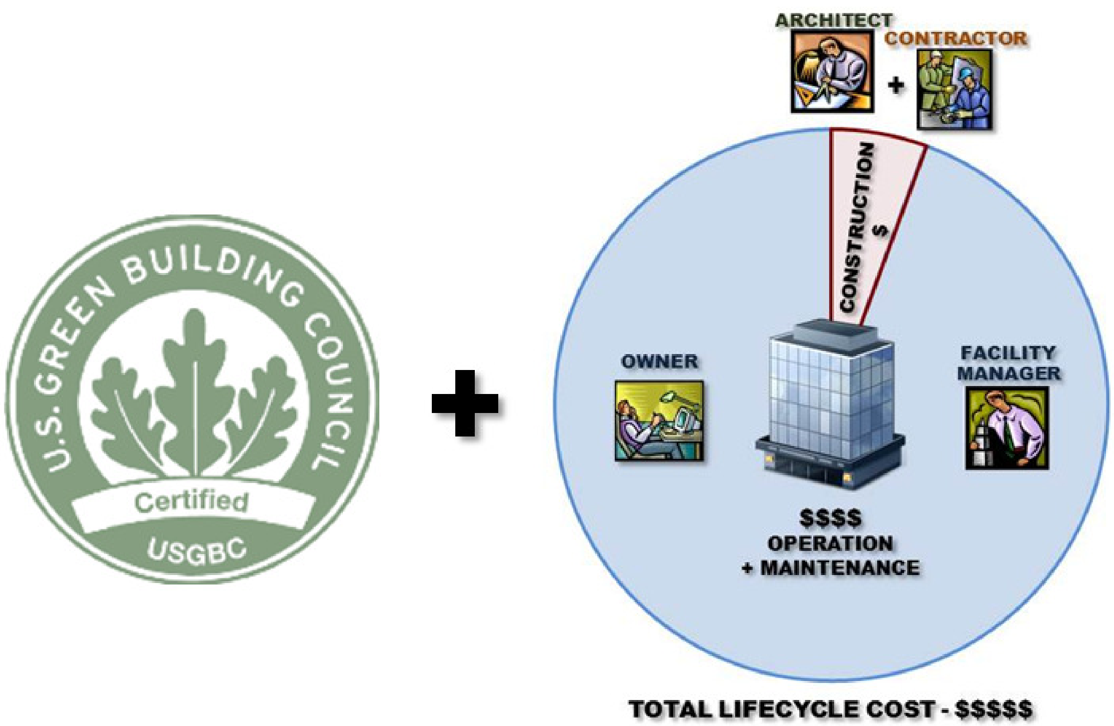


Figure 1. The impact of LEED rating systems on cost (Daniels, 2012).

This thesis follows the style of American Society of Civil Engineers (ASCE).

Figure 1 suggests that obtaining LEED certification for buildings may have an impact on both first cost and life cycle cost, but as will be demonstrated in this paper, the nature of that relationship is not explicit, and this is a source of risk for owners considering pursuing LEED certification with their facilities. This study will develop a lifecycle costing algorithm that provides a preliminary estimate of the potential financial return of Heating, Ventilation, and Air Conditioning and Lighting (HVAC&L) equipment, at increasing thresholds of energy performance - as defined by the United States Building Council's (USGBC), Leadership in Energy and Environmental Design's (LEED) Energy and Atmosphere (EA) 1 rating metric.

The financial data obtained in this study is adjusted per the time value of money over the manufacturer's warranty period of ten years, and plotted graphically to compare first cost against ownership costs at each increasing EA1 threshold of energy performance. The results are adjusted for the regional factors of climate, procurement, and operational expenses, and can be used to identify equipment that produces an optimal internal rate of return (IRR). The lifecycle costs of various systems can be compared at incremental performance thresholds, thereby providing owner groups and facility managers with insight regarding total cost of ownership (TCO) when selecting HVAC&L systems.

Pro Forma Estimates

As projects move from concept to construction, the accuracy of estimates performed during various phases of development increase in proportion to the completeness and accuracy of the design and the construction drawings. Accordingly, estimates performed at the concept phase will be inherently less accurate than estimates performed during the construction documents phase (Manfredonia et al., 2010). It is important to note that construction cost appraisals performed during the conceptual phase of a project typically utilize square foot estimates based on historical data to produce general approximations of first costs, but these early estimates mak no attempt to predict operational or lifecycle or energy costs. While construction costs for various types of buildings can be approximated on a square foot basis (R.S. Means, 2012), lifecycle estimates require that the building design be developed to the point that systems have been specified in order to be analyzed for system specific performance criteria; and this is particularly true in the case of complex and/or high cost systems such as HVAC&L.

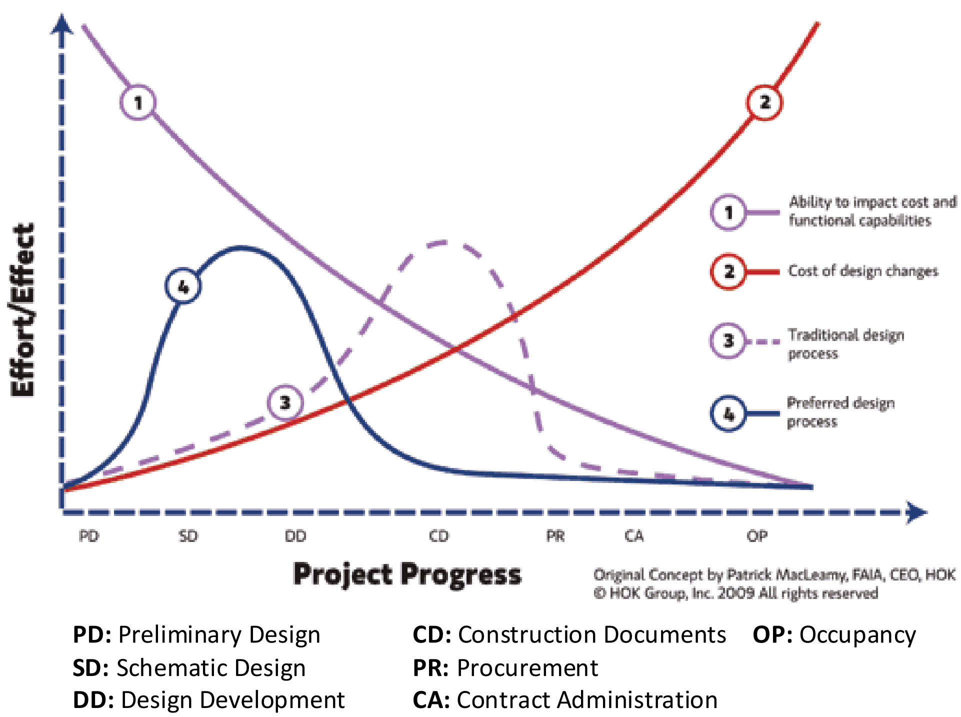


Figure 2. MacLearny curve (American Institute of Architects California Council, 2007).

The MacLeamy curve, illustrated in Figure 2 demonstrates that decisions made early in a project's development have the greatest ability to impact budget and schedule, with the least impact on project cost. This is because informed decisions at the beginning of the design process reduce the likelihood of changes being required to either the design or construction further in development. Coordination and collaboration in the beginning of a project reduces the amount of rework and streamlines production, improves schedule, and reduces cost (American Institute of Architects California Council, 2007). To that end, a positive result of this study is that the findings will provide owner groups and facility managers with a resource that will allow them to develop insight into the costs benefit relationship of various building systems as early as possible in the development process.

In traditional development sequencing, the Architect and Engineer team (A&E) are typically first to be retained in order to produce a design and select building systems that will become the basis of future estimates and analysis. Unfortunately, at the point at which the design is robust enough to produce accurate lifecycle estimates, the owner has already invested significant time and capital; and this investment that may prove insufficient if the design does not perform as desired and requires additional rework. By developing an early understanding of possible cost benefit relationships between building first cost and lifecycle cost, owners can make preliminary decisions regarding target performance criteria and capital investments during predesign; even before commissioning the A&E team, and as early as in the financial pro forma phase.

Database Lifecycle Estimates

In a manner similar to the way in which conceptual phase construction cost estimates can be obtained from historical data, this paper references several distinct energy consumption databases produced by third party organizations including to obtain target energy performance thresholds for facilities of similar program, size, and geographic regions. Sources include:

- The Department of Energy (DOE), Commercial Building Benchmarks (2009).
- The Department of Energy, Building Energy Data Book (2004).
- The Commercial Buildings Energy Consumption Survey (CBECS), (2003).
- The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), Energy Design Guidelines (2012).

This data can be utilized to produce preliminary lifecycle estimates of a facility's anticipated energy consumption Once energy benchmarks for an anticipated project have been established by utilizing database averages, the projected level of energy consumption can then be incrementally reduced to determine progressively increasing thresholds of energy performance for the attainment of LEED EA1 credit points. Various HVAC&L systems can then be selected for evaluation in terms of achieving these performance targets, and further compared on the basis of first cost, and projected lifecycle savings. By plotting the cost v. performance of various building systems, owners can leverage "database lifecycle estimates" to identify the building systems most in line with their business objectives.

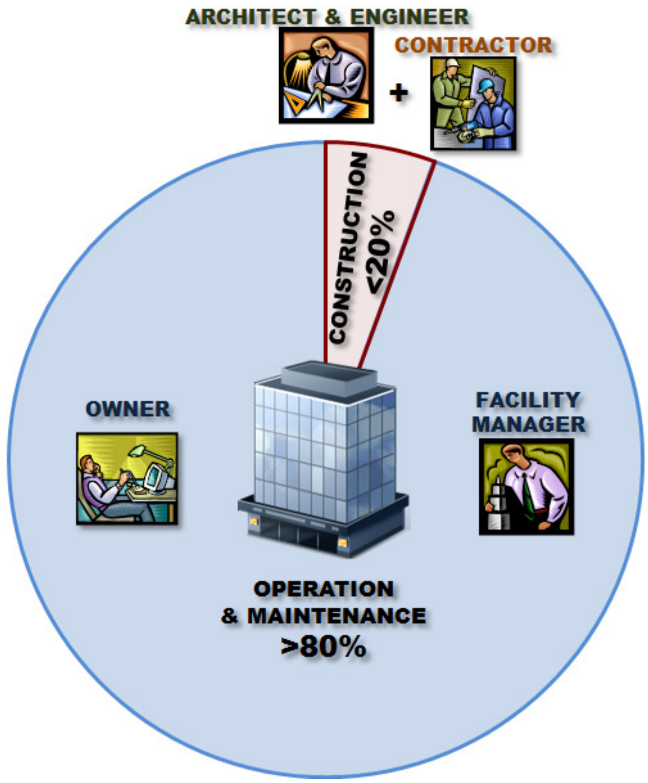


Figure 3. Total ownership cost (Daniels, 2012).

It is important to note that design and construction represent less than 20% of the total cost of ownership, and operations and maintenance (O&M) represent more than 80% (Dell'Isola, 2003). Architects, engineers and contractors focus almost exclusively on issues relating to first cost. This is because the contractual obligations of the typical design and construction contracts conclude at project delivery, and with it the designer's and builder's obligation to the project (AIA Contract Documents, 2007and Consensus Doc, 2012). O&M considerations are traditionally considered the responsibility of the owner and facility manager and hence beyond the scope of services provide by the design and build teams. Ironically, as a result of the contractual rewards structure and the large capital outlays required during construction, owners tend to focus heavily on the

First. However, Figure 3 clearly indicates that for owner operators, O&M data is five and a half times more critical than first cost considerations; and that O&M, not design nor construction, represents the owner's most significant financial concern.

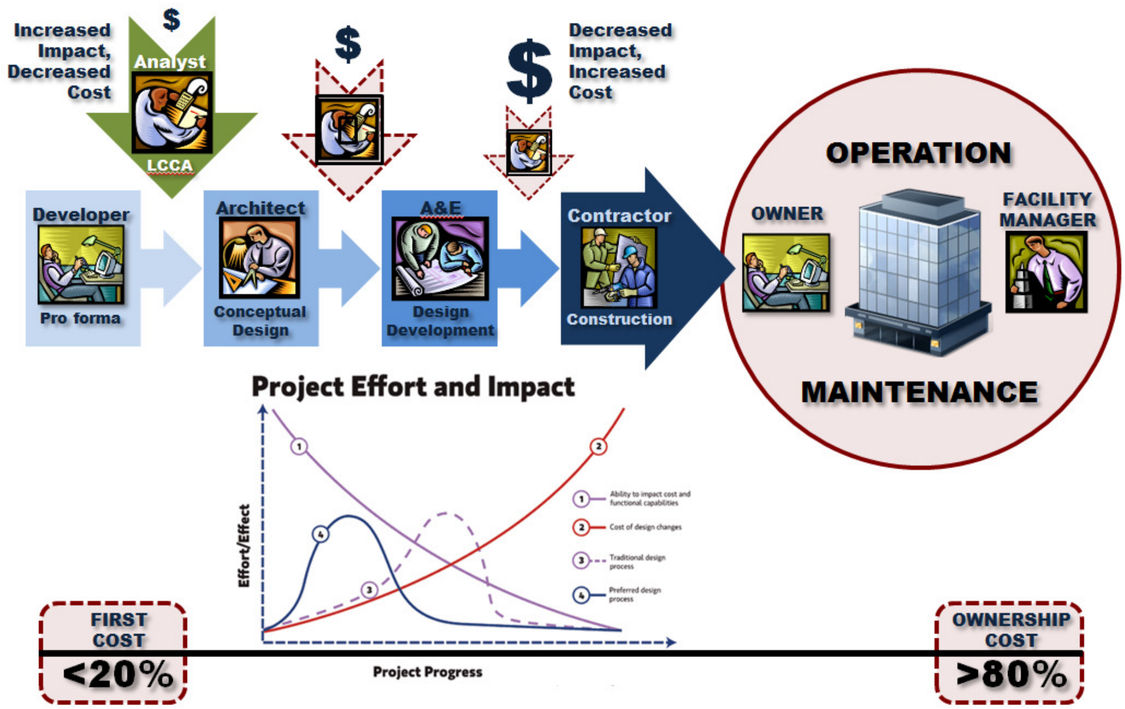


Figure 4. Phasing and LCCA cost effectiveness (Daniels, 2012).

Due to the approximate nature and inherent variability in national energy databases, this study is not intended to provide an accurate Lifecycle Cost Analysis, rather to suggest a method for preliminary O&M cost comparisons in an area of significant importance where there was none before. As illustrated in Figure 4, when O&M comparisons are provided early in the development process, the approximate nature of preliminary estimates may be offset by the increased insight and effectiveness these analyses provide before significant capital resources have been committed.

Based on the premise that there must first be a design in order to have something to be analyzed, Lifecycle Cost Analysis (LCCA) traditionally occurs late in the design process when building details have been sufficiently developed. The ability of the lifecycle analyst to provide meaningful input (with the least required rework and the least impact on other disciplines) is diminished the further the project moves from concept to completion. In order for lifecycle estimates to have the greatest positive impact on the development process, it must occur as early as possible in the predesign phases when project decisions are critical. As the project reaches completion in subsequent phases, the value of an LCCA is reduced as the cost to make changes to the existing design increases. When considered within the context of the MacLeamy curve it is apparent that O&M data has the greatest potential to provide increased saving when provided as early as possible. (American Institute of Architects California Council, 2007).

Problem Statement | Lifecycle Cost Analysis

LEED assessments of energy savings are articulated in terms of a code mandated baseline performance and compared to the potential operational savings of high performing systems (USGBC, 2009). A preliminary review of sustainable construction literature revealed few performance evaluation techniques that provided a comparison of complete lifecycle costs (including discounted cash values of purchase, installation, and operational costs), and none that provided for regional adjustments for procurement or operation. However, when determining total cost of ownership, owners and facility managers make more accurate predictions regarding anticipate future returns of current capital investments when utilizing a LCCA (Fuller, 2010).

This study will demonstrate that because many sustainable rating systems do not consider the time value of money or regional variations in first costs or energy costs, the accuracy of predicted returns of capital investments are inherently unreliable. For example, the USGBC's LEED rating system has been criticized for implying lifecycle cost savings that have failed to materialize. In October 2010, the USGBC was named as a defendant in a class action lawsuit in which the USGBC was charged with, "...fraudulently misleading consumers and fraudulently misrepresenting energy performance of buildings certified under its LEED rating systems…" (Roberts, 2010).

Research Objectives

The primary research objectives of the paper include the following:

- Determine if a correlation exists between LEED building certifications and reduced ownership costs.
- Identify variables that significantly impact HVAC&L system selection and facility performance.
- Determine if regional factors (including climate zone and energy cost) can produce variances in anticipated HVAC&L ownership costs.
- Determine if whole building simulations are necessary to predict energy lifecycle performance.

Hypothesis | Relativity

A preliminary review of the literature suggests that anticipated HVAC&L systems lifecycle cost vary (Figure 5), dependent upon regional factors including:

- Climate zone
- Energy prices
- Discount factors
- First cost
- Sustainable behavior of the owner group

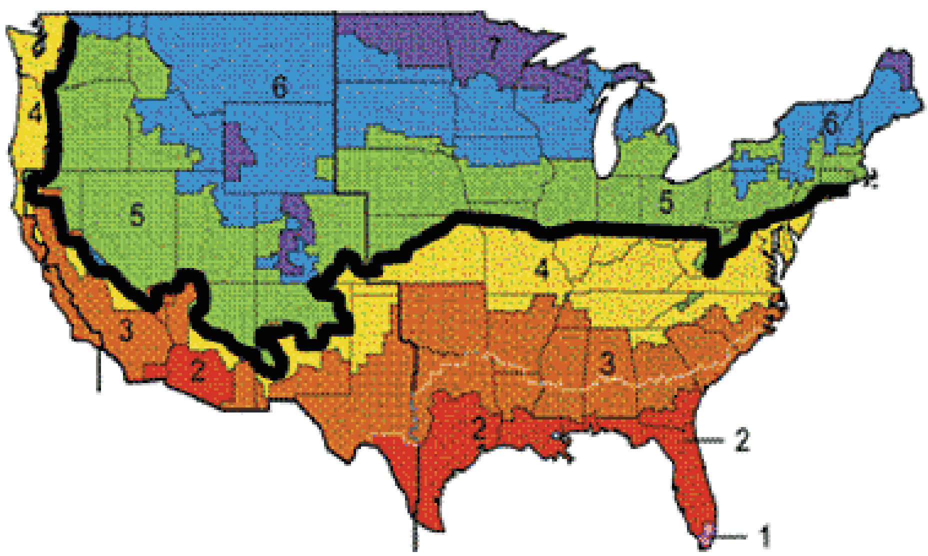


Figure 5. Climate zones (ASHRAE 2007)

Example 1: In Alaska where the temperature is extreme and energy costs are high, investment in high performance systems may be offset by operational savings.

Example 2: In North Carolina, where the climate is temperate and energy costs are moderate, investment in high performance systems may not prove fiscally sound.

Scope | Limitations and Delimitations

Lifecycle Cost Analysis

A lifecycle cost analysis is an established procedural method for assessing the total cost of facility ownership. This study is not a true LCCA because rather than identifying the complete lifecycle performance of a particular facility, this study attempts to provide owners with generic price and performance breakpoints based on regional averages, that can then be used to identify the LEED rating most in line with business objectives. The scope of this study is restricted to the operational internal rate of return (IRR) of new capital investments.

Leadership in Energy and Environmental Design (LEED)

The USGBC's LEED EA1 was selected as the energy performance metric for this study because LEED is the most widely used and commonly accepted environmental performance rating system currently employed by in the United States design and construction industry (Fowler and Rauch, 2006).

HVAC Equipment and LEED EA1

HVAC and Lighting systems costs comparisons and the associated LEED EA1 performance metrics were selected as the topic of this study because HVAC&L equipment and their associated energy demands typically represent the most significant first cost and ongoing operational expense of new construction and renovation budgets (Commercial Building Energy Consumption Survey (CBECS), 2003).

Equipment Service Life

While many HVAC&L systems are designed to be in operation for over 50 years, for the purpose of this study a system's relevant service life is assumed to be 10 years, so as to correlate with the industry standard 10 year manufacturer's warranty. Systems with a manufacturer's warranty provide a financial guarantee of performance, and can be assumed to operate reliably within the parameters outlined in the specifications (or be repaired or replaced at the manufacturer's expense) (Sweets Network, 2010). This study also attempts to minimize the confounding impact of non-standard maintenance procedures on equipment life by assuming that substandard maintenance procedures would invalidate warranty provisions. Used equipment is not considered because of the variability of used system maintenance and performance.

Salvage Value

Though systems may be expected to perform beyond the warranty period, data outside of this range is not considered because of the lack of uniform operational data and the absence of a guarantee of equipment reliability. Considerations of residual values are not considered for reasons including the unpredictability of future resale markets, the impact of new legislative or technology performance requirements on obsolete systems, and the confounding impact of comparing multiple systems with variable design lives. Determining an estimate for the salvage value of equipment is considered beyond the scope of this report, and is not considered.

Cost per Square Foot

Values are analyzed in terms of annual operating cost. Costs will be recorded both on a lump sum basis, to compare gross figures, as well as dollars per square foot, to facilitate case study comparisons.

Discount Factor: Interest Rate

The study allows users to input the interest rate data most reflective of current market conditions. Interest rate reflects the current U.S. Treasury rate.

CHAPTER II

REVIEW OF LITERATURE

Sustainability Dividend

A commonly referenced definition for sustainability was established in the 1987 United Nations World Commission on Environment and Development (WCED):

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

While the WCED provided a conceptual definition for sustainability, it did not articulated the technologies by which this objective could be obtained, nor the metrics by which sustainable objectives should be quantified. The net result of sustainable initiatives leveraged in the marketplace can be described as a “sustainability dividend”, and quantifies the impact that these initiatives can have on the quadruple bottom line of business practices (economic), social organizations (cultural), sustainable practices (environment), and sensory value (experiential) (Booth, 2008).

Sustainability has often been perceived as negatively impacting profitability; however the prudent application of sustainable practices can be implemented to maximize value, minimize operational overhead, and more closely align real estate products with the consumer market. The practical employment of sustainable technologies and practices can therefore add value to real estate investments and provide a competitive edge for savvy entrepreneurs seeking to more effectively align a premium real estate product with market needs (Booth, 2008).

The astute application of sustainable techniques can serve to optimize net operating income by reducing operational overheads. The use of energy efficiency improvements and water conservation strategies can directly reduce operating costs. And the employment of quality enhancing strategies such as indoor environmental quality measures and public transport systems may improve a facility's perceived quality which may in turn lead to increased rent rolls and improved tenant satisfaction (Penny, 2012).

Intangible Benefits

Variables to be considered in determining the viability of pursuing a sustainability rating are numerous, and have varying impact on ownership cost and marketability. Quantifiable benefits to obtaining LEED certifications for buildings may include first cost savings or increased lease rates and reduced operating cost as well as intangible economic benefits (Fuller and Petersen, 1995):

- Public relations and improved marketing
- Corporate branding
- Health and productivity
- Environmental responsibility
- Social benefits

While the scope of intangible considerations are outside the realm of this study, it is reasonable to assume that owner groups are the party best suited to assign value to sustainability initiatives within the context of their particular corporate values.

Certification System Name	Availability	Third-Party Certification
BREEAM (Building Research Establishment's Environmental Assessment Method)	For the UK market	
CASBEE (Comprehensive Assessment System for Building Environmental Efficiency)	For the Japan market	
CEPAS (Comprehensive Environmental Performance Assessment Scheme)	For the Hong Kong market	
Energy Star Portfolio Manager		
EPLabel		
Estidama Pearl Rating System	For the Abu Dhabi market	
Green Globes™ US	√	√
HQE (High Environmental Quality)	For the France market	
LEED® (Leadership in Energy and Environmental Design)	√	√
Living Building Challenge	√	√
NABERS (National Australian Built Environment Rating System)	For the Australia market	
SB Tool	For the international market, but not adopted in the U.S. yet	
SPiRiT (Sustainable Project Rating Tool)	√	Self Compliance
Three Star System	For the China Market	

Figure 6. Screening of green building rating systems (Wang et al., 2012)

Sustainability Rating Systems and Energy Performance

There are numerous rating systems utilized by the building industry to evaluate the sustainable characteristics and energy performance of buildings and building systems. Rating systems vary by country, industry, and even between public and commercial developments. As Figure 6 illustrates, rating systems are as varied as the facilities they evaluate, and understanding the applications of each is critical in determining the best application of each rating system.

The four largest sustainable rating systems involved in the construction industry include the USGBC, with regional dominance in the United States, Canada, and India; the Building Research Establishment Environmental Assessment Method (BREEAM), with regional dominance in the U.K. and Europe; the Council Alliance for a Sustainable Built Environment (CASBE) in Japan; and Green Star in Australia and New Zealand (Reed et al., 2009). LEED unlike Casbee, Green Globes and BREEAM, has been readily adopted in the U.S., and is prominent in media and industry outreach programs (Fowler and Rauch, 2006).

States, government organizations, and even commercial companies have produced metrics to evaluate building system performance, and these tools vary in terms of the method of evaluation, the criteria being measured, and the established baselines, as well as the systems being analyzed. Several proprietary and widely employed design and analysis tools are currently at the disposal of A&E teams, including Energy Star, ECONPACK, Energy-10, Building Life Cycle Cost Program, and Success Estimator

(Estimating and Cost Management System). Each of these metrics however must be executed appropriately within the context of a particular project and cannot easily be cross compared (Fuller and Petersen, 1995). The following U.S. organizations publish LCCA metrics that provide effective first cost and lifecycle cost comparisons:

- American Society for Testing and Materials (ASTM) International—Publishes standards that support LCCA.
- Sustainable Buildings Industry Council (SBIC)—Offers workshops on Designing Low-Energy Buildings that include instruction in using Energy-10 software.
- U.S. Army Corps of Engineers Life-Cycle Cost Module
- U.S. Cost—Conducts training workshops for SuccessEstimator and Tri-Services Parametric Estimating System (TPES) models several times each year.
- Building for Environmental and Economic Sustainability (BEES) (The National Institute of Standards and Technology,2012)
- Energy Cost Calculators (U.S. Department of Energy (DOE), 2012).

The energy codes referenced by these LCCA metrics themselves vary by location - as dictated by regional legislative environments. The state of California for example enacted its Title 24 Energy Code which increased the performance standards for buildings beyond those required by other national building codes, and San Francisco's Residential Energy and Water Conservation Requirements is a municipal ordinance that again exceeds the requirements of Title 24. As such it can often be difficult to compare the performance metrics of a national code, with the metrics of a regionally mandated state or municipal code (California Energy Commission (CEC, 2005). The evaluations performed in this study will comply with the U.S. national code baselines as established by ASHRAE/IESNA Standard 90.1 (ASHRAE, 2007).

Leadership in Energy and Environmental Design (LEED)

LEED was established to promote sustainable approaches toward the built environment, to disseminate "best practice" technologies. LEED provides independent third party verification of sustainable practices for a variety of building programs, and utilizes key performance indicators to assess a building's alignment with sustainable building principles. Points are assigned on a 1-110 scale, in the areas of Sustainable Site, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation and Design. Buildings are awarded increased levels of certifications dependent upon the level of accumulated points and sustainable performance (Appendix 1).

- Certified: 40-49 points
- Silver: 50-59 points
- Gold: 60-79 points
- Platinum: 80-110 points

LEED is an open format credentialing system developed and administered in 2000 by the United States Green Building Council through a consensus of industry professionals. LEED is evolving and has seen several iterations as it is constantly raising the bar to be qualified as a sustainable performer (Lockwood, 2006). LEED for Building Design and Construction (BD+C), and Operation and Maintenance (O+M), are variants of the LEED rating system intended to optimize energy performance of existing buildings, and to serve as a roadmap to achieve demonstrated energy improvements (Hicks, 2005).

In its capacity as a third party verification tool, LEED also serves to counter a phenomenon known as “Green Washing”. Green washing is a practice in which developers, designers, or builders claim to employ sustainable practices, but for which there was no objective criteria upon which to verify their claims (Hoffman and Hoffman, 2009). So while third party metrics serve as verification of sustainable practices, and as sustainable buildings tend to demonstrate improved energy performance over national averages, the correlation between sustainable buildings and an overall reduction in lifecycle cost has not been conclusively demonstrated (Kats, 2003).

Sustainability Bias

A review of the literature regarding the lifecycle cost of suitability rating systems reveals an institutionalized bias on the part of the analyzing agencies, and an implicit conflict of interest in the method of evaluation. Current literature regarding the evaluation of energy savings are regularly published by advocates of sustainability initiatives with a vested interest in demonstrating cost savings. Because there is no attempt in LEED to analyze the impact of first cost investments on total ownership cost, it is in the best interest of these groups to reinforce the ideology of sustainable practice, rather than tangibly demonstrate financial return of owner groups (Ecopreneurist, 2011).

There is no LEED process by which a regional lifecycle assessment is performed to corroborate the sustainability savings implied by the USGBC (USGBC 2009); and best practice principles require a dispassionate review of the data that must be independently verified in order to provide owner groups with unbiased business information. The following bullets summarize the general finding from a review of USGBC literature:

- The LEED rating system implies, but do not quantify operational or lifecycle savings (USGBC 2009).
- The LEED rating system evaluates systems performance, not total ownership cost (USGBC 2009).
- The LEED rating system utilizes averaged national performance data by referencing national codes, and is hence not representative of regional conditions (USGBC 2009).
- The LEED rating system does not consider systems costs (USGBC 2009).

Energy | Systems and Strategies to Reduce Energy Cost

Healthcare facilities, which include Hospitals, clinics, inpatient and outpatient facilities, are among the most intensive energy users in the nation spending more than 6 billion a year in energy costs alone, and health care is the fourth largest consumer of energy by building type, consuming 515 trillion BTU/year (Runy, 2003). When one considers that health care facilities represent a considerably smaller proportion of the built environment than commercial or office types, the intensity of energy use in hospitals is even more striking. Inpatient health care facilities alone consume 38.5 million BTUs per year - more than offices, stores, and schools combined (Runy, 2003). The American Society of Heating Refrigeration and Air conditioning Engineers (ASHRAE), states that an average healthcare facility in the U.S. uses 250% more energy than an average commercial building (Hatton, Sullivan, and Newland, 2010).

The scale of this ongoing operational expense has health care operators taking notice. Because every $1 of revenue is eroded by the cost of goods and services, operational expense, and tax expense, an organization may require between $7-$20 in new revenue generation to have the same positive effect on net income as just $1 of general expense reduction. Energy conservation therefore amounts to a potentially significant improvement to an organization's net income, and administrators recognizing this fact have made energy efficiency an organizational priority. And because HVAC&L represent the majority of a facility's energy demand (CBECS, 2003), administrators have further developed targeted optimization strategies as a key element of their expense cutting practices.

Many healthcare facilities still utilize HVAC solutions dating from the 1920's, including steam pipe heating, and centrally controlled cooling which has a significant impact on a facility's operating expenses (Nichols, 2007). Sixty five percent of administrators are paying more attention to energy costs that they were just 1 year ago, and 99% believe cost savings is the primary reason to invest in energy systems, but nearly half, 45%, claimed budget restrictions were their main limitation in implementing efficiency measures (Smith, 2011). In response, third party facilitators have arisen to assume the upfront capital costs in exchange for a percentage of future savings. Examples of shared cost financial arrangements include energy performance contracts, power purchasing agreements, and shared savings agreements.

Lifecycle Cost | Cost Analysis Methodologies

LCCA is a method for assessing the total cost of facility ownership, typically performed by design professionals on a case by case basis. It is initiated at the direction of owner groups who use the information to make cost effective design and construction decisions (Todd, 2010). A LCCA can be a time consuming and expensive process that typically identifies lifecycle savings for owner operators.

To be effective LCCAs must consider as many relevant cost inputs as possible so as to convey an accurate evaluation of acquisition, operation and salvage expenses. LCCAs are also utilized to compare the cost benefit advantages of numerous competing financial opportunities for facility operators, and can provide guidance for the selection of HVAC systems among competing options in which first costs may must be considered in relation to operational savings (Sawyer, 2011). Per a facility managers' need to predict costs and expenses, LCCAs have demonstrated strong correlations between facility efficiency and financial performance and have been found to be particularly useful in the evaluation of Healthcare Facilities that are intense consumers of energy resources. (Halim and Kirkham, 2006).

Lifecycle Cost, Internal Rate of Return, Payback Period, and Net Savings are all terms used to describe the process of interpreting economic performance of competing systems. LCCAs can be performed by a variety of professionals at any stage of the building project; for a healthcare facility LCCA can be performed by including architects, engineers, building economists, or quantity surveyors in the design evaluation process (Snodgrass, 2008). And because an LCCAs can itself be a resource intensive exercise, many software vendors have produced proprietary costing applications to facilitate the process. In any LCCA the primary step in economic evaluation is to determine the varying impacts of alternative designs of buildings and building systems and to quantify these effects and express them in dollars. These costs generally fall into one or more of the following categories:

- Initial costs—purchase, acquisition, construction costs
- Fuel costs
- Operation, maintenance, and repair costs
- Replacement costs
- Residual values—resale or salvage values or disposal costs
- Finance charges—loan interest payments
- Non-monetary benefits or costs

The basic Formula for Calculating Life-cycle cost is as follows (National Institute of Building Sciences, 2012):

LCC = I + Repl — Res + E + W + OM&R + O

- LCC = Total LCC in present-value (PV) dollars of a given alternative
- I = PV investment costs (if incurred at base date, they need not be discounted)
- Repl = PV capital replacement costs
- Res = PV residual value (resale value, salvage value) less disposal costs
- E = PV of energy costs
- W = PV of water costs
- OM&R = PV of non-fuel operating, maintenance and repair costs
- = PV of other costs (e.g., contract costs for ESPCs or UESCs)

Employee salaries and benefits constitute the largest expenditures for facility operators (Whitestone Research, 2012). This is particularly true of building types that employ large numbers of highly paid technically skilled workers, such as hospitals. Accordingly many analysts suggest design changes that positively impact employee performance should also be considered as of the most cost effective elements of building performance (National Institute of Building Sciences, 2010), however this paper restricts its focus to areas under the control of the design team.

Lifecycle Cost Analysis: Owner Operators v. Speculators

The viability of utilizing an LCCA on speculative projects is currently being debated. Increases in first costs may be exchanged for lowered overall lifecycle cost, but this presumes a long term financial commitment on the part of owner groups (Fuller and Petersen, 1995). If owner groups are committed to the long term performance of a building, then it may be in their best financial interest to invest in an LCCA (United States Department of Transportation, 2002). If however the owner is speculative in nature, the interest in facility performance is short term – in which case emphasizing the lowest first cost, and maximizing the immediate resale value is of the highest priority to the owner.

Because owner operators are typically more vested in the long term performance of their facilities, it is reasonable to assume that owner operators will be more interested in obtaining LEED credentialed facilities than will be speculative investors. It is plausible to assume that because there is no savings incentive for a speculative development, that these facilities may dismiss the potential lifecycle returns implied by a LCCA in favor of maximizing the immediate return on investment by minimizing construction costs. Additionally, it must be stated that because LEED points do not have an intrinsic dollar value associated with them, LCCA's do not reference or quantify the "value" of LEED certification unless explicitly requested to do so.

The Role of Facility Management

Facility Managers supervise operational functions, construction projects, and technology, mechanical and electrical systems within a facility. While their job is not directly related to the actual business performed in the building, they are an integral piece of their company's functionality. The scope of Facilities Management can range from asset management, involving the global positioning of real estate portfolios to maximize an organizations internal rate of return, to providing for the basic requirements of a tenant's health safety and welfare - including operational maintenance, services, systems, equipment, security, and energy performance. (Rondeau, 2006). The Facility Manager acts as the owner's principal representative in matters associated with ongoing operational expense. In this regard, the professional insight and operational expertise embodied in the profession can positively inform the A&E decisions in the facility that the facility manager will continue to operate long after project delivery (Kingwill, J., 2009).

Upon its founding in 1970, The Facility Management Institute defined Facilities Management (FM) as "Managing and coordinating, people, process, and place issues." In 2006 the International Facility Management Association (IFMA) defines Facilities Management as "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology" (International Facility Management Association, 2012).

The rapid evolution of the “definition of practice” reflects the continuing evolution of the FM industry. From its inception in 1970, the FM profession has striven to increase owner value by maximizing the efficient operation of the built environment, as well as optimizing the strategic allocation of financial assets to improve the quality of occupied space and the productivity of workflow. The means by which these goals are realized varies, and is unique to the needs of the organization and facility being served (Teicholz, 2001).

Project Delivery Method and Energy Performance

Owner groups have typically defined time and budget efficiency as the ultimate metric of design and construction teams; as a result, project delivery systems have been developed to incentivize these objectives. Low construction overheads are often achieved by architects and contractors through the selection of systems and materials with low purchase and installation costs, often at the expense of higher operation and maintenance (O&M) overheads. Because design and construction represents less than 20% of total ownership costs, emphasizing first costs as the dominate performance metric does not necessarily align with the owner group’s strategic goal of maximizing lifecycle performance through improved facility O&M.

Because the motivation of the design and build team, comprised of the Architect, Engineer and Contractor can vary significantly based on contractual obligations, and the method financial reward, careful selection of the project delivery method can have significant impact both first cost and lifecycle cost. A brief summary of three most common project delivery methods in the U.S. highlights some of the contractual motivations during the design and construction phase that can have lasting impacts on the operational performance of a facility (AIA Contract Documents, 2007).

Design Bid Build Project Delivery Contract

The Design Bid Build (DBB) project delivery contract illustrated in Figure 7 represents the standard delivery method utilized by the construction industry to procure a facility (American Institute of Architects (AIA) Contract Documents, 2007). DBB is the benchmark by which all other methods are compared, and it is included in this report to provide a reference for contractual obligations and accountability. In the DBB method, the owner retains a designer to produce the construction drawings from which the lowest bidding contractor is selected to build the project. The owner maintains two distinct contracts with the architect and the contractor (Figure 8), and there is little input from either the owner or the contractor during the design phase of the project (American Institute of Architects (AIA) Contract Documents, 2007).

Figure 7. Typical DBB project delivery lifecycle and team members (Daniels, 2012)

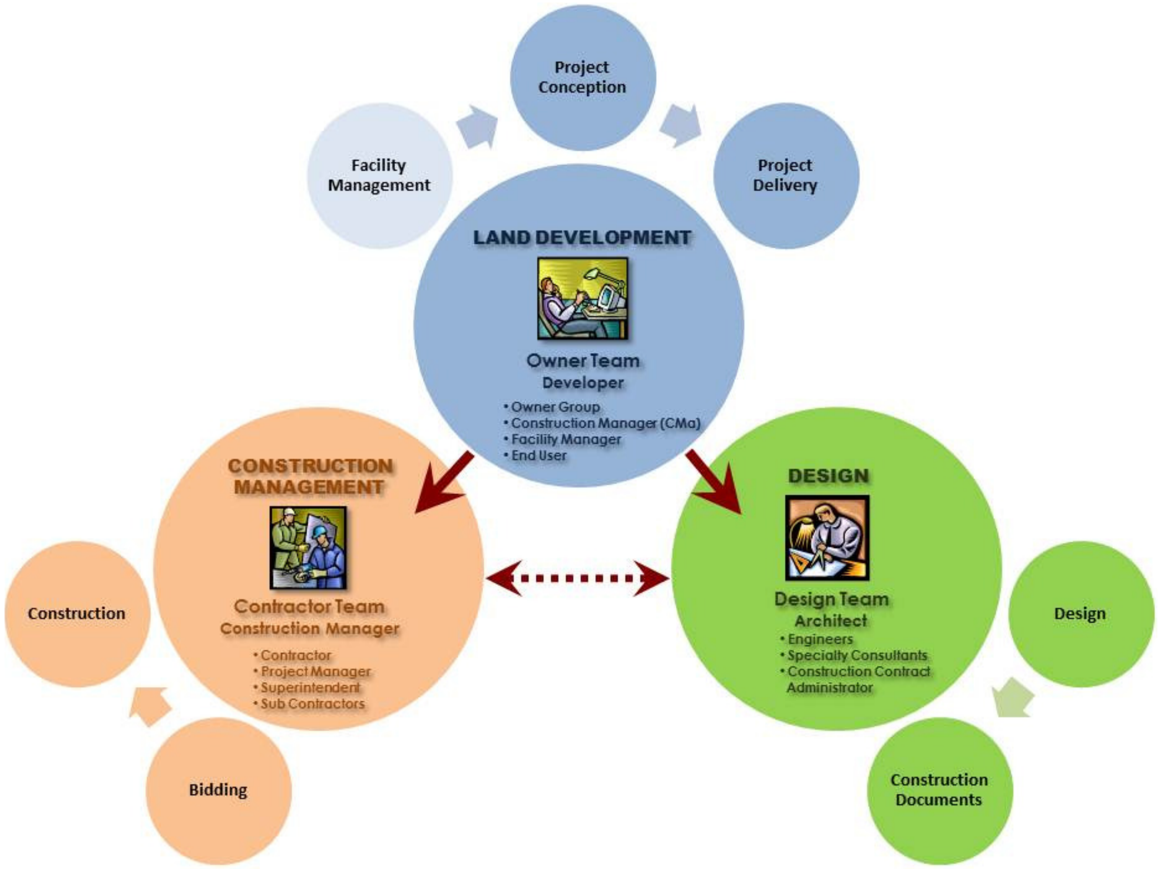


Figure 8. Project delivery method: Design Bid Build (Daniels, 2012)

Contractually motivated behaviors promoted by the DBB that are in conflict with an owner's long term financial interest include the following (ConsensusDocs, 2012):

- Designer and builder performance rewards are exclusively based on the criteria of lowest production cost and fastest completion.
- Inexpensive materials and systems selection is incentivized, and positively impacts the design/build team's financial reward. Expensive systems and materials are disincentivized, and negatively impact the design and build team's reward.

- Lack of communication during design and construction often result in claims and delays, fostering an adversarial relationship between parties.
- To avoid design changes and budget inflation, the owner's facility management teams are often excluded from the design and building process.
- There is no mandated evaluation of lifecycle or systems performance during the design process.
- There is no design or build team accountability for future building performance after project delivery.
- There is a contractual incentive for the design/build team to undervalue lifecycle performance. There is a contractual disincentive for the design/build team to be concerned about O&M performance.

Under the DBB method the builder retains any savings between the projects' contracted price, and its delivered price. This strategy encourages expediency during design, in the form of construction documents and specifications that favor low cost products, and during construction, with means and methods of assembly that emphasize expediency. With the exception of errors and omissions, warranty and liability issues, most AIA and ConsensusDocs contractual obligations are dissolved upon project completion, and as illustrated in Figure 9, the architect and contractor are not responsible or involved with operational issues after project delivery (Construction Specifications Institute (CSI), 2005)

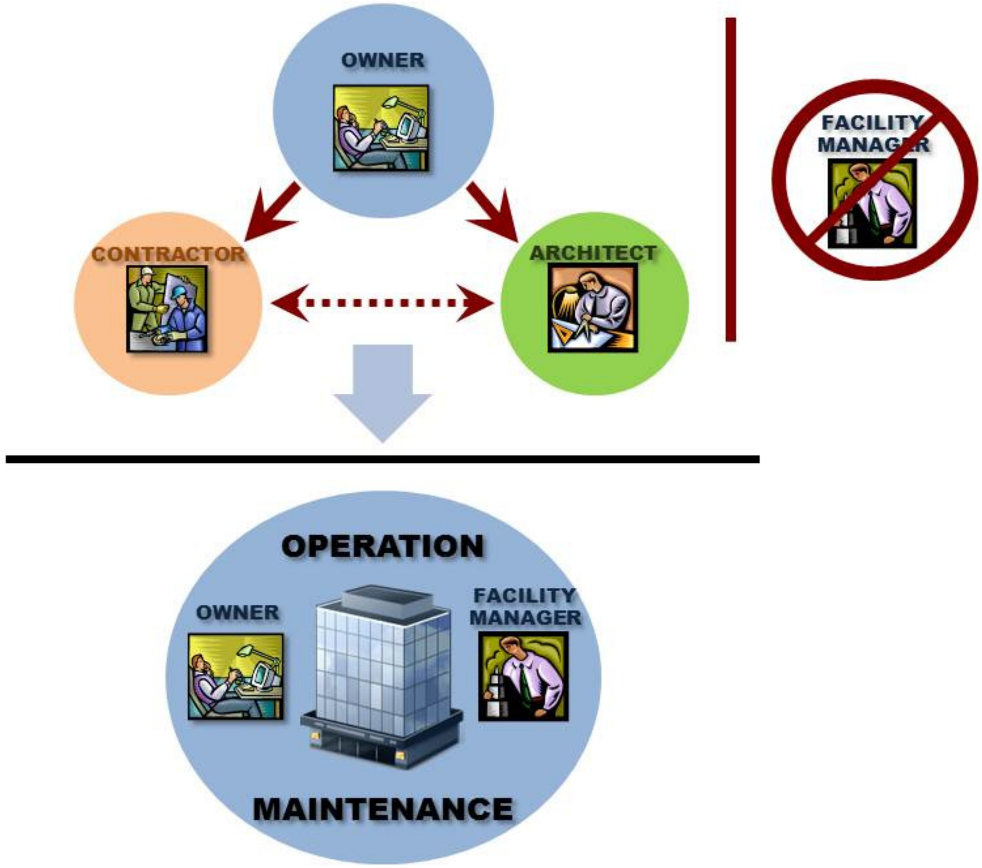


Figure 9. Project accountability: Design Bid Build (Daniels, 2012)

Construction Manager at Risk

In the Construction Manager at Risk (CMr) delivery system (Figure 10), the contractor is partnered with a designer early in the conceptual phase to share resources and streamline the design and build process (Construction Management Association of America (CMAA), 2009). Both the designer and builder are rewarded for delivering the facility to the owner under budget and ahead of schedule, and because of increased collaboration between the teams, owner objectives are more likely to be realized with fewer conflicts.

Like CMr and DBB, all contractual obligations for the project are dissolved upon project completion (ConsensusDocs, 2012).

Although CMr provides early collaboration between the design and build teams and hence improves productivity, the contractually motivated behaviors promoted by the CMr that are in conflict with an owner's long term financial interest are almost identical to those previously listed for DBB (Figure 11).

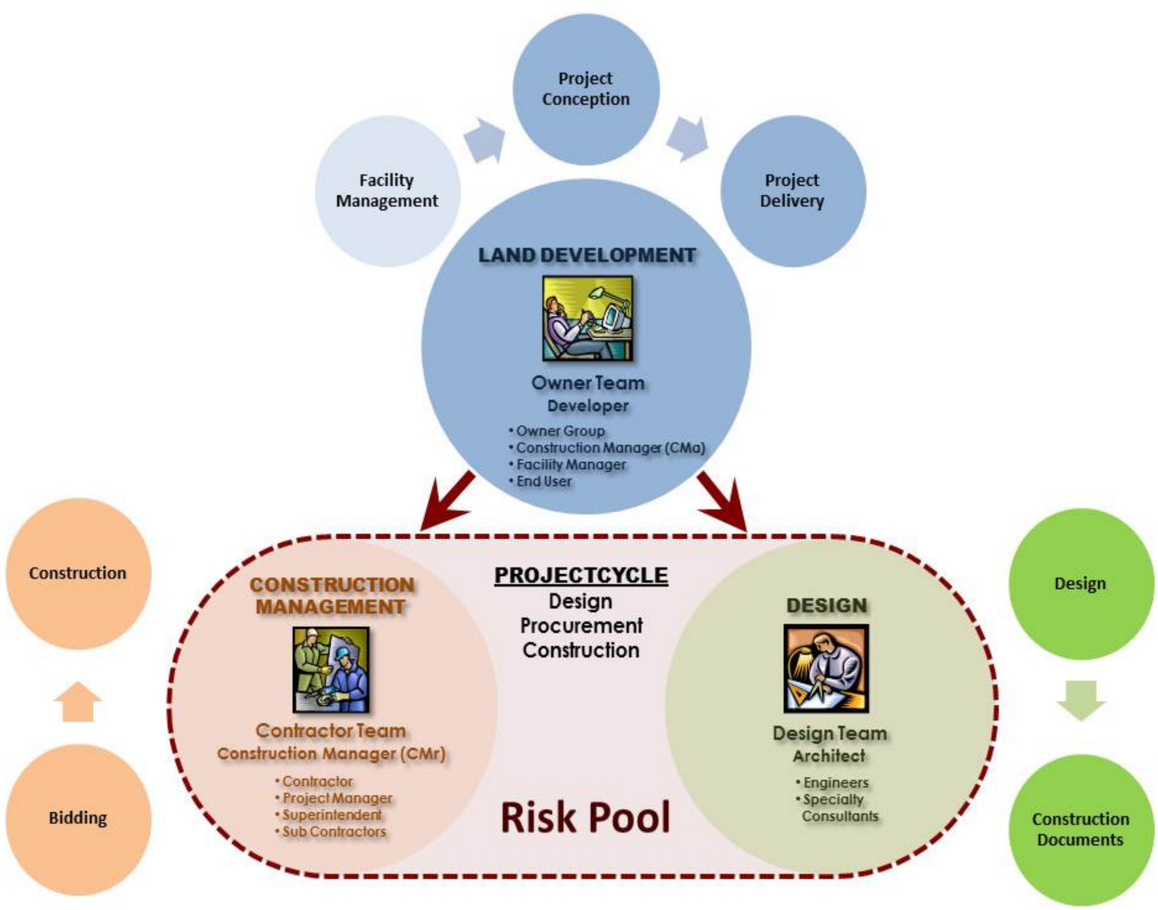


Figure 10. Project delivery method: Construction Manager at Risk (Daniels, 2012)

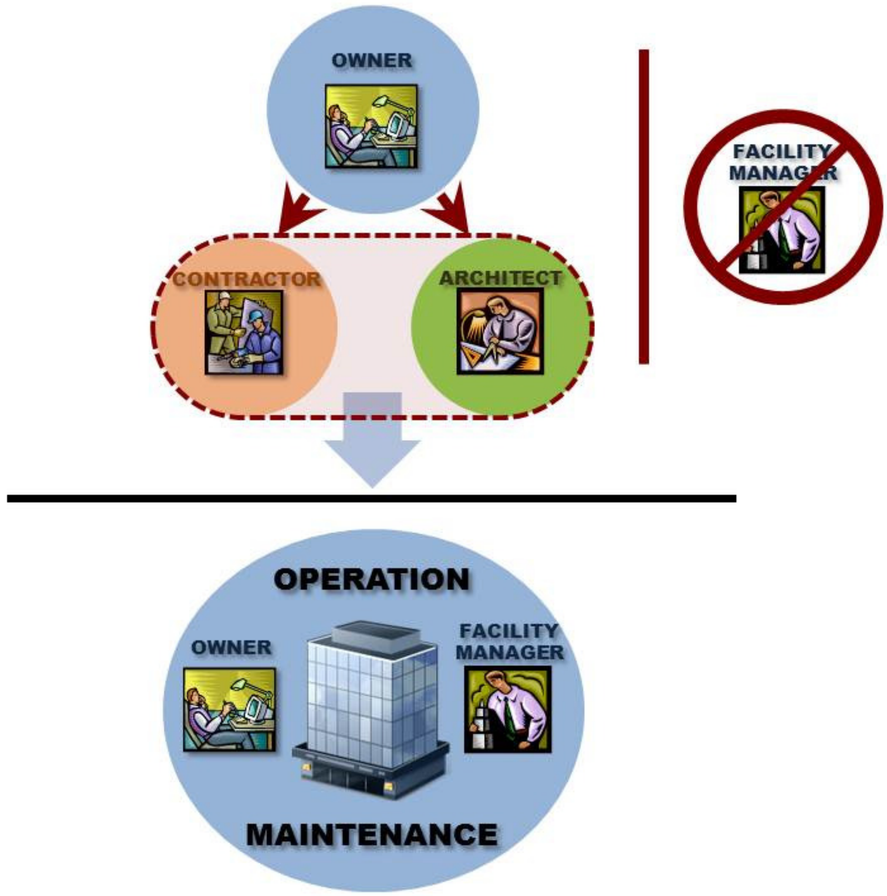


Figure 11. Project accountability: Construction Manager at Risk (Daniels, 2012)

Integrated Project Delivery

Integrated Project Delivery (IPD) is a relatively new project delivery system that emphasizes early project coordination between the owner, designer and builder. IPD utilizes a unique multiparty agreement in which all parties are equally vested in the contract and have an equal performance obligation to every other party (Figure 12). Increased collaboration facilitates project efficiencies and reduces conflict with the goal of shared savings. Unlike DBB and CMr, liability risk is reduced because all design and construction decisions are collaboratively vetted and approved – increasing cooperation and minimizing conflict, change orders and delays (National Association of State Facilities Administrators, et al. 2010).

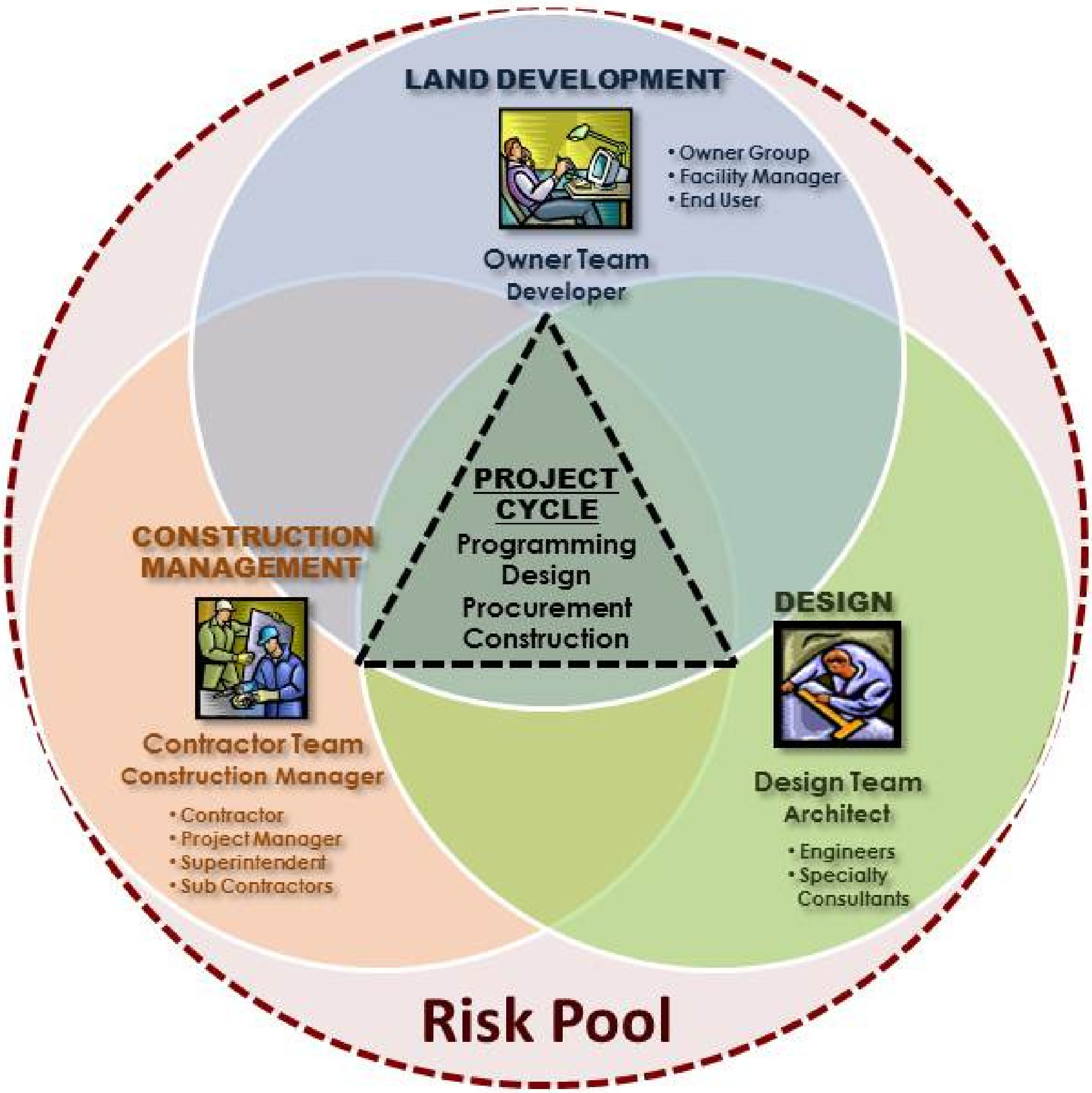


Figure 12. Project delivery method: Integrated Project Delivery (Daniels, 2012)

The following provides a summary of contractual benefits of the IPD system (AIA California Council, 2007)

- Conceptualization, Criteria Design, and Detailed Design phases involve early input from the broader integrated team and result in greater levels of coordination and completion - before the documentation and construction phases are started.
- High level of early coordination provides for shorter construction times.
- IPD requires a sophisticated owner group with the authority to provide binding direction to the design and build team.

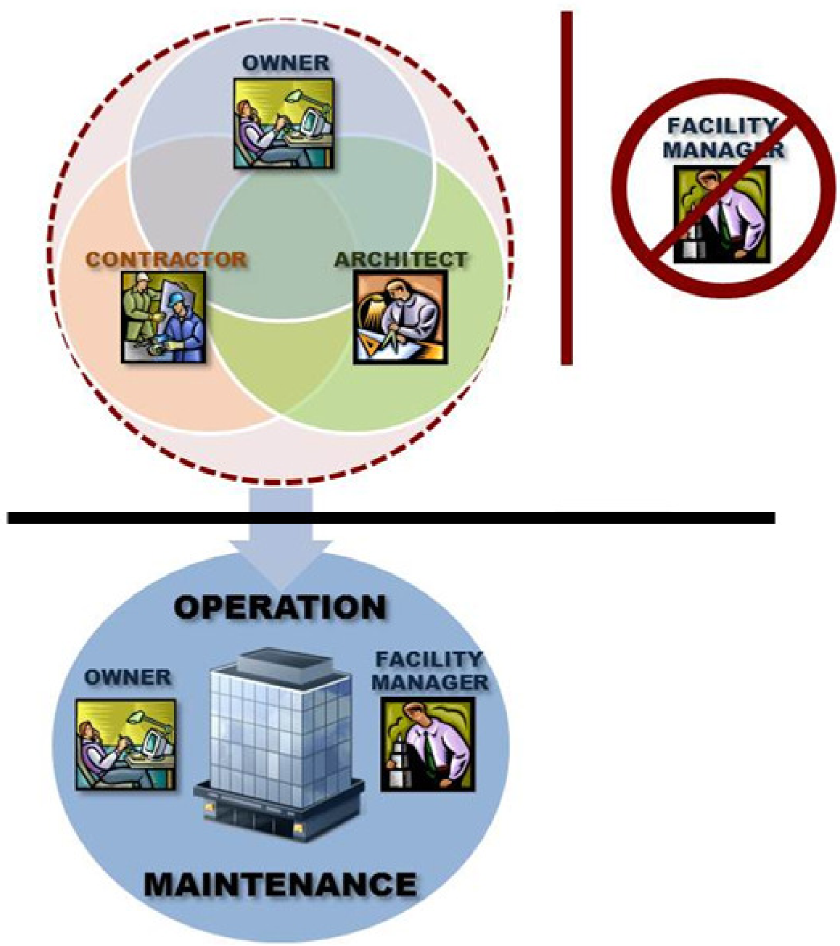


Figure 13. Project accountability: Integrated Project Delivery (Daniels, 2012)

IPD accountability issues are similar to those of CMr .The designer and builder are rewarded for delivering the facility to the owner under budget and ahead of schedule. However, because of increased collaboration between the teams, owner objectives are more likely to be realized. Like CMr and DBB, most contractual obligations for the project are dissolved upon project completion (Thomsen, 2008).

IPD provides the earliest and most comprehensive form of collaboration between the design and build teams, however, like DBB and CMr, the contractually motivated behaviors promoted by the IPL contract that are in conflict with the owner's lifecycle financial interest are almost identical to those previously listed for DBB (Figure 13).

Although various project delivery methods may improve collaboration and productivity, all existing contracting methods focus exclusively on reducing first cost and improving construction schedules (which represent less than 20% of ownership cost). Because the financial reward structure of contractual agreements disincentivizes lifecycle savings, it behooves owners to recognize the misalignment of organizational goals and party motivation. As the financier and the party with the greatest risk, only the owner can insist that future contracting methods recognize the relevance of lifecycle issues on their organization's bottom line.

CHAPTER III

RESEARCH METHODS

Population of Interest | U.S. Healthcare Facilities

For the purpose of this research, the populations of interest are mid-size U.S. outpatient facilities between 150,000-250,000 ft^2 in Houston, TX (ASHRAE climate zone 2A). Mid-size facilities are selected because the 150,000-250,000 ft^2 target group represents a greater sample of the built environment than do “large buildings”, but also employ HVAC system types that are characteristic of the equipment utilized in larger buildings. For example, while a mid-size building might employ one or two chillers or boilers in a machine room, a larger building might employ three or four of the same types of equipment. By virtue of their scale, small building HVAC solutions do not typically require the use of the larger, more sophisticated and expensive HVAC&L systems that are the focus of this paper.

For the purpose of this study outpatient facilities have been selected as a subset of the Healthcare group because of the high availability of O&M data, and the sophistication of operators in record maintenance, as well as the industry’s typically high volume of energy consumption (Runy, 2003). The methods utilized in this example maybe applied to any building type. National averages for climate, labor, and systems cost data are generic and of questionable value in an owners cost benefit analysis for a regionally specific capital investment. Accordingly, regional factors are considered independently.

Data Collection

Figure 14 provides a graphic flowchart to illustrate the method used to collect and compare data necessary to estimate a facility's HVAC&L loads based on historical performance data without the need to develop a building design.

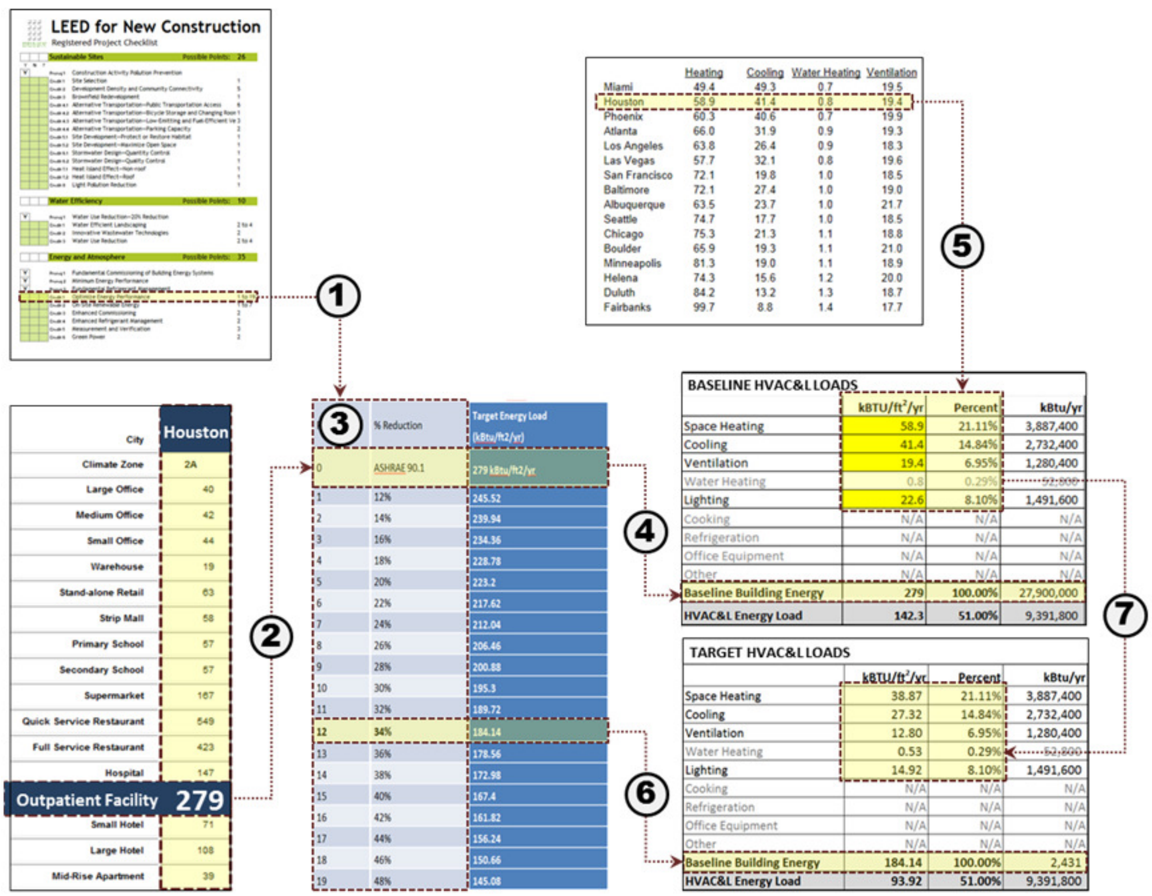


Figure 14. Research method: Data collection flow chart (Daniels, 2012)

1. The LEED EA1 credit is used to establish increasing levels of energy performance (USGBC, 2009).

2. The Department of Energy Commercial Building Benchmarks is utilized to obtain region specific ASHRAE 90.1 energy consumption baselines for relevant building programs in kBTU/ft^2/yr format (DOE, 2009).
3. A table is utilized to reduce the baseline building load to correspond to LEED points
4. The DOE building baseline is multiplied by the proposed building size to establish the baseline kBTU/yr (100,000ft^2 example).
5. The Energy Benchmarks for Newly Constructed Outpatient Buildings establishes the percentage of energy used by HVAC&L systems in a region specific ASHRAE 90.1 compliant outpatient facility (Building Energy Data Book, 2004).
6. Table three is utilized to determine the building target energy load associate with user selected LEED EA1 credit points.
7. Baseline HVAC&L are proportionately reduced to estimate the new target energy loads for HVAC&L systems for various levels of LEED points.

Data Analysis

Figure 15 illustrates how the findings from Figure 14 can be utilized to identify HVAC&L performance parameters, and to estimate costs necessary to evaluate systems that may best suit the organizations LEED certification objectives. Various levels of certification and energy performance can be compared with regard to first cost (relevant to financing), and the discounted ten year ownership cost (relevant to operations).

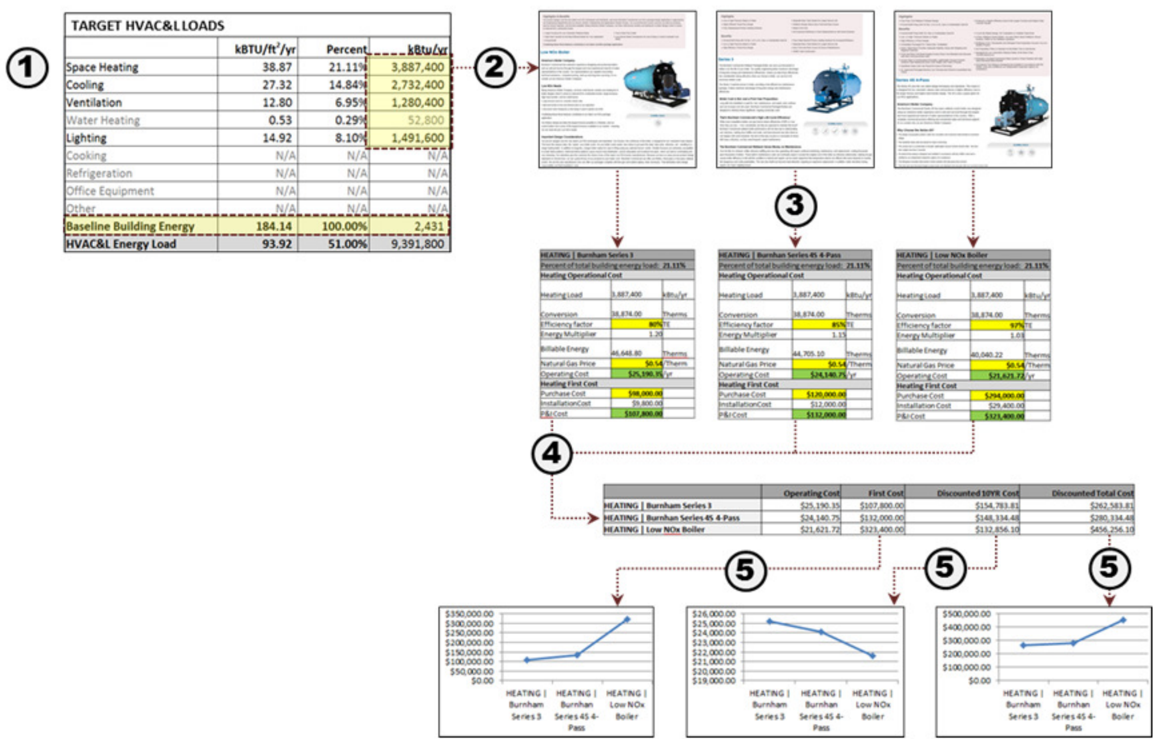


Figure 15. Research method: Data analysis flow chart (Daniels, 2012)

1. Obtain target HVAC&L loads from “Data Collection” results.
2. Identify HVAC&L system models and manufacturers that can preform to target levels.
    a. Example: Evaluate cost and performance specifications for three competing Burnham Boilers obtained from manufacturer.
3. Utilize assessment framework to enter region specific variables for various products:
    a. First cost | Purchase + Installation
    b. Product efficiency factor
    c. Energy Cost
4. Utilize a comparative table to summarize findings:
    a. First cost | Purchase + Installation
    b. Discounted 10 year energy cost
    c. Discounted 10 year total cost
5. Graphically plot systems to compare findings for each of the above performance categories to assess performance.

CHAPTER IV

FINDINGS

Data Generation | Establishing Baseline Metrics

System performance thresholds are often based on national energy averages for total building performance. The attainment of 1-19 credit points per LEED EA1 requires a demonstrated reduction in a facility's total energy loads when compared to the minimum performance threshold established per ASHRAE Standard 90.1. Because engineers typically require a building design upon which to base their analysis, estimating LEED credit points is typically not possible without a whole building energy simulation. This convention presents cost analysis conducted in the predesign phases with two unique problems:

1. How to estimate total energy use without an actual building design to asses.
2. How to determine what percentage of a building's total energy use is attributable to HVAC&L systems and in what proportion.

Problem 1: Estimating Baseline and Target Energy Use without a Building Design

Because a building's design is typically not established in predesign phases, estimates for energy use must be derived by means other than the LEED prescribed whole building energy modeling method. Furthermore, in order for an estimate to be relevant for projects of various sizes, energy estimates must be obtained in a regionally adjusted kBTU/ft^2/yr format. In this way, predicted energy demands can be easily amended in response to changes in size, program, and location. The U.S. Department of Energy (DOE) has developed the Standard Benchmark Energy Utilization Index (SBEUI) derived from 16 commercial building types to quantify Energy Use Intensities (EUIs), which represents the amount of energy a building consumes per year on a square foot basis. Obtained in annual energy use per square foot per year (kBTU/ft^2/yr), these values correspond to the minimum energy thresholds established by ASHRAE 90.1.

City	Miami	Houston	Phoenix	Atlanta	Los Angeles	Las Vegas
Climate Zone	1A	2A	2b	3A	3B	3B
Large Office	38	40	38	38	32	34
Medium Office	39	42	40	41	33	37
Small Office	44	44	43	41	33	39
Warehouse	30	19	19	18	14	18
Stand-alone Retail	62	63	60	61	44	56
Strip Mall	56	58	57	62	44	57
Primary School	57	57	55	55	46	52
Secondary School	56	57	55	57	42	54
Supermarket	158	167	159	170	153	158
Quick Service Restaurant	535	549	538	561	496	541
Full Service Restaurant	404	423	409	440	374	418
Hospital	145	147	138	142	137	135
Outpatient Facility	280	279	278	274	254	277
Small Hotel	71	71	69	71	62	68
Large Hotel	99	108	100	116	105	105
Mid-Rise Apartment	39	39	38	38	31	36

Figure 16. New construction energy use intensities (EUIs) [kBTU/ft^2/yr] based on regional averages (DOE, 2009)

As illustrated in Figure 16, this study utilizes the SBEUI to determine the minimum energy performance threshold required for new outpatient facilities; it does not however represent the entire commercial building stock, nor is it to be used to quantify the energy performance of a single building. For a project in Houston, Texas, the SBEUI value is 279 kBTU/ft^2/yr.

An Excel spreadsheet (Appendix 2: CD) can be utilized to catalog baseline values and perform automatic estimating calculations based on energy consumption, first cost, and lifecycle cost. Table 1 for example, utilizes the baseline energy value obtained from Figure 16, and applies the LEED EA1 thresholds to calculate an incremental 2% energy reduction for progressively increasing LEED points. Accordingly, we can utilize the SBEUI baseline for any program in any region, and permit Excel to automatically construct a table of correlated LEED points and associated kBTU/ft^2/yr values.

This process allows the researcher to obtain an appropriate target energy load early in the predesign phase without requiring a building design and without the need to construct a whole building energy simulation. Table 1 demonstrates the LEED target energy thresholds for an outpatient facility in Houston, TX..

Table 1. LEED EA1 Threshold table (1-19 Points): Target energy loads derived as a percent reduction below ASHRAE 90.1 baseline (USGBC, 2009)

LEED Points	**% Reduction of Total Energy Consumption per ASHRAE 90.1 Baseline**	**Target Energy Load ($kBTU/ft^2/yr$)**
0	***ASHRAE 90.1 Baseline***	***279 $kBTU/ft^2/yr$***
1	12%	245.52
2	14%	239.94
3	16%	234.36
4	18%	228.78
5	20%	223.2
6	22%	217.62
7	24%	212.04
8	26%	206.46
9	28%	200.88
10	30%	195.3
11	32%	189.72
12	34% *(Example)*	184.14
13	36%	178.56
14	38%	172.98
15	40%	167.4
16	42%	161.82
17	44%	156.24
18	46%	150.66
19	48%	145.08

Problem 2: HVAC&L Costs as a Percentage of Total Energy Costs

Because HVAC&L loads do not represent ALL of a facility's energy use, it is necessary to determine what percentage of the total building load the HVAC&L demand actually represents, and how sensitive the attainment of EA1 points are to adjustments in the HVAC&L systems selection. Figure 17 presents national EUI averages derived from Commercial Building Energy Consumption Survey (CBECS) and the California Commercial End-Use Survey (CEUS), while Figure 18 quantifies the percentage of total energy use derived specifically from HVAC&L systems (chillers, boilers, fans, and luminaires).

Figure 19 demonstrate that the sum of HVAC loads (kBTU/ft2/yr: Heating 38.1,Cooling 7.2, Ventilation 3.3) account for 48.6 kBTU/ft2/yr; over half, 51.4% of an outpatient facility's 94.6 kBTU/ft2/yr total energy consumption. And when lighting loads (22.6 kBTU/ft2/yr) are added to the evaluation, the total HVAC&L loads account for 71.2 kBTU/ft2/yr, or 75.3% of the total building load (CBECS, 2003).

Site energy, kBtu/sf-yr	CBECS (mean)	CEUS (median)	CEUS (mean)[1]	CBECS (mean) %	CEUS (median) %	CEUS (mean) %
Data points	144	27	(varies)			
Total Energy	94.6	43.5	63.6			
Space Heating	38.1	6.3	7.6	40%	14%	12%
Cooling	7.2	5.9	8.9	8%	14%	14%
Ventilation	3.3	2.9	3.5	3%	7%	6%
Water Heating	2.5	5.6	7.3	3%	13%	12%
Lighting	22.6	11.5	16.2	24%	26%	25%
Cooking	Q	0.4	0.6	-	1%	1%
Refrigeration	3.5	2.4	3.4	4%	5%	5%
Office Equipment	3.9[1]	3.2	4.4	4%	7%	7%
Other	13.2	5.5	11.8	14%	13%	19%

[1] Calculated from distributions of EUIs for individual end-uses. "Process" end-use excluded for insufficient data.
[2] Sum of "office equipment" in Table E2 and "computer" in Table E4. In Table E2, EUI for computers is listed a 1.0 for all building types. Office equipment EUIs are roughly the same in E2 and E4.

Figure 17. Outpatient/clinic end use intensities: National averages (CBECS, 2003)

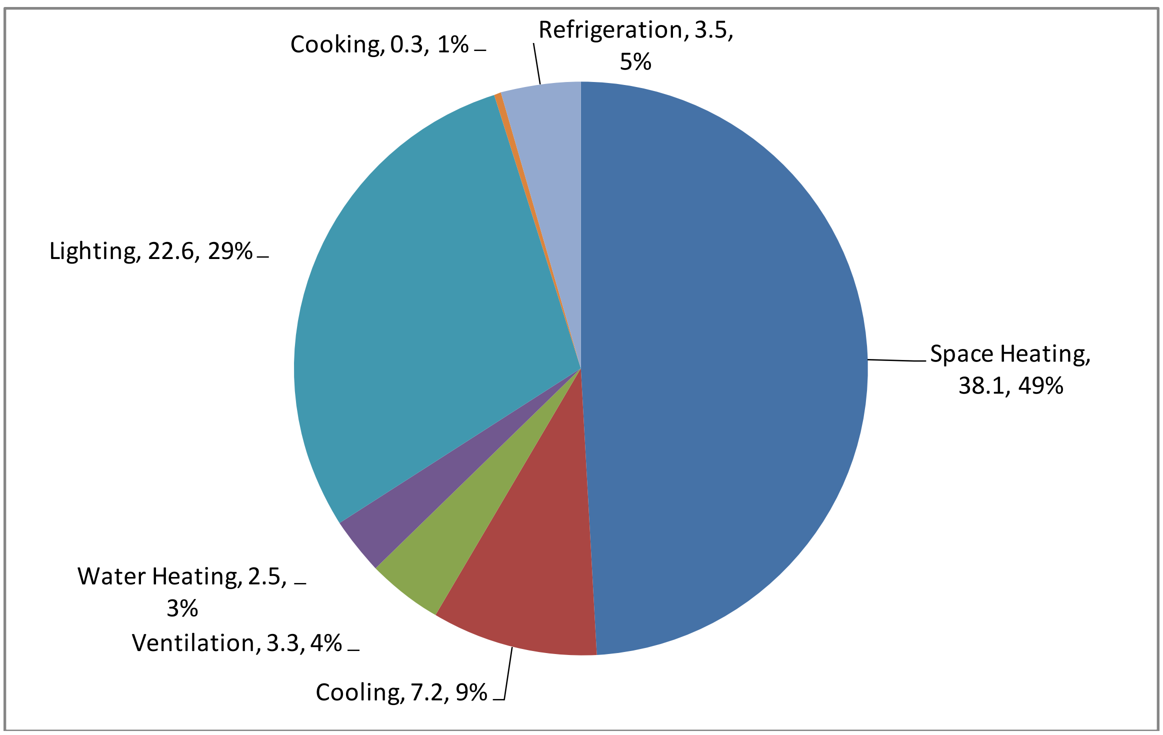


Figure 18. National averages for outpatient building systems end use intensities (Generated per data obtained from Figure 19)

	IECC Climate Zone	Heating	Cooling	Water Heating	Ventilation
Miami	1A	49.4	49.3	0.7	19.5
Houston	2A	58.9	41.4	0.8	19.4
Phoenix	2B	60.3	40.6	0.7	19.9
Atlanta	3A	66.0	31.9	0.9	19.3
Los Angeles	3B	63.8	26.4	0.9	18.3
Las Vegas	3B	57.7	32.1	0.8	19.6
San Francisco	3C	72.1	19.8	1.0	18.5
Baltimore	4A	72.1	27.4	1.0	19.0
Albuquerque	4B	63.5	23.7	1.0	21.7
Seattle	4C	74.7	17.7	1.0	18.5
Chicago	5A	75.3	21.3	1.1	18.8
Boulder	5B	65.9	19.3	1.1	21.0
Minneapolis	6A	81.3	19.0	1.1	18.9
Helena	6B	74.3	15.6	1.2	20.0
Duluth	7	84.2	13.2	1.3	18.7
Fairbanks	8	99.7	8.8	1.4	17.7

Note(s): Commercial building energy benchmarks are based off of the current stock of commercial buildings and are designed to provide a consistent baseline to compare building performance in energy-use simulations. The benchmark building had 40,932 square feet and 3 floors. Benchmark interior lighting energy = 13.02 thousand Btu/SF. Interior equipment energy consumption = 46.01 thousand Btu/SF.

Figure 19. Energy benchmarks for newly constructed outpatient buildings, by selected city and end-use (kBTU/ft^2) (Building Energy Data Book, 2004)

Table 2. National and regional energy benchmark comparisons (CBECS, 2003 and Building Energy Data Book, 2004).

Systems	**CBECS: National Values** (kBTU/ft^2/yr)	**Energy Databook: Houston, TX Values** (kBTU/ft^2/yr)	**Delta** (kBTU/ft^2/yr)
Heating	38.1	58.9	+20.8
Ventilation	3.3	19.4	+16.1
Cooling	7.2	41.4	+34.2
Lighting	22.6	N/A	N/A

It is important to note the significant differences obtained for End Use Intensities (EUI) derived from national CBECS averages (presented in Figure 17), with the regionally adjusted Building Energy Data Book EUI presented in Figure 19. Table 2 indicates the range between national data and region values. Explanations for the range may be attributable to regional variations in climate and energy costs, but the variance is so significant one might call into question the accuracy of the data itself.

In an attempt to verify the CBECS and Building Energy Data Book figures, ASHRAE's Energy Guidelines (2012), summarized in Figure 20, provides a comparison of regional energy use, derived from computer simulated models rather than survey records. This data was referenced in order to triangulate the previous figures and better identify the source of the national and regional energy variance. ASHRAE's figures more closely support the findings of the Building Energy Data Book's regional data, and also demonstrate significant variation in HVAC loads dependent on climate zone.

Heating loads increase with ascending (northern) climate loads and cooling loads increase with descending (southern) climate zones. Interior lighting loads remain predictably consistent as interior lighting levels are not impacted by climate, and hence not subject to regional fluctuation. Exterior lighting loads however correlate with climate zone as a result of reduced day lighting further away from the equator (ASHRAE, 2012).

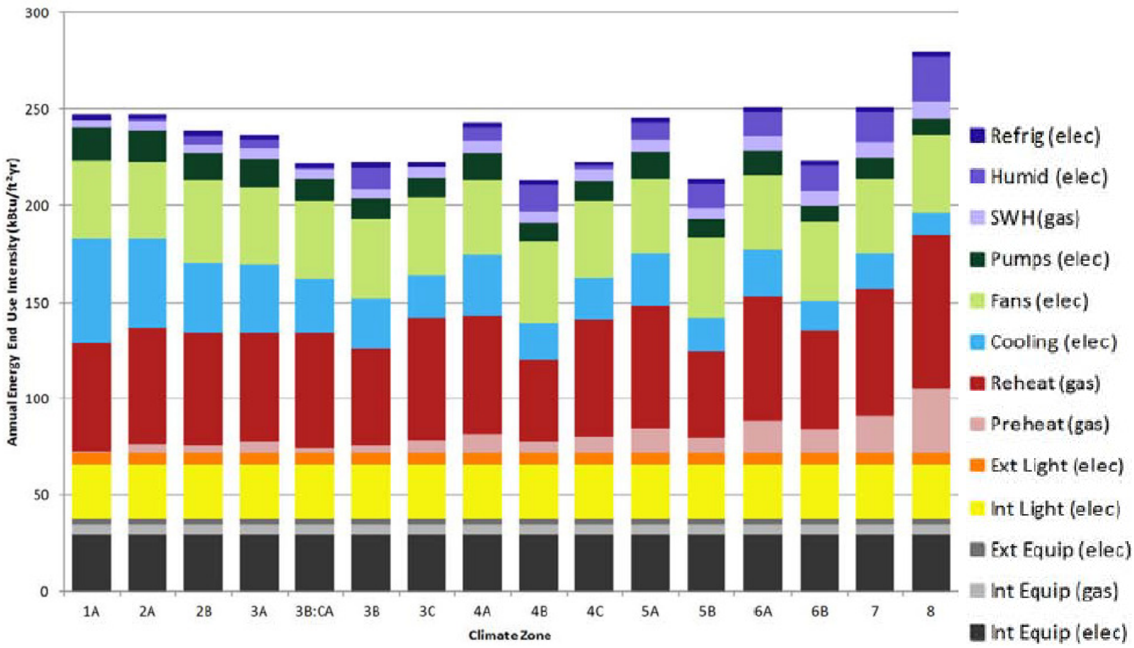


Figure 20. Comparison of regional averages for outpatient end use intensities per building systems (ASHRAE, 2012)

It is important to note that a facility's "total energy load" includes loads that are not typically included in whole building modeling simulations; and hence are not considered when determining eligibility for LEED points. This is chiefly attributable to the fact that design teams deal almost exclusively with building HVAC&L systems. Hence anticipating highly variable equipment plug loads is beyond the scope of the A&E team. Values included in the CBECS survey beyond the scope of LEED energy simulations often include "Office Equipment" loads at 3.9%, and "Other" loads at 13.2%.

Non design loads represent energy consumption by a facility that cannot be accurately modeled in whole building simulations because they represent highly variable loads that are subject to the occupants use preferences. These loads highlighted in italics include Cooking, Refrigeration, Office Equipment, and Other.

Table 3. Site Energy: National averages for outpatient end use intensities per building systems (CBECS, 2003)

	kBTU/ft^2/yr	Percent
Space Heating	38.1	40.3%
Ventilation	3.3	3.5%
Cooling	7.2	7.6%
Lighting	22.6	23.9%
Water Heating	**2.5**	**2.6%**
Cooking	***0.3***	***0.3%***
Refrigeration	***3.5***	***3.7%***
Office Equipment	*3.9*	*4.1%*
Other	*13.2*	*14%*
Total Energy	**94.6**	**100.00%**
Total: HVAC & L	**71.2**	**75.3%**
Design Energy	**77.5**	**100%**
Design: HVAC & L	**71.2**	**91.9%**

Table 4. Site Energy: Regional averages for outpatient end use intensities per building systems (Building Energy Data Book, 2004)

	kBTU/ft^2/yr	**Percent**
Space Heating	58.9	21.1%
Ventilation	19.4	6.9%
Cooling	41.4	14.8%
Lighting	22.6	8.1%
Water Heating	**0.8**	**0.3%**
Cooking		
Refrigeration		
Office Equipment		
Other	*136.7*	*48.8%*
Total Energy	**279**	**100%**
Total: HVAC & L	**142.3**	**50.9%**

As demonstrated in Table 3 referencing national energy averages, if the EUI of non-design loads are removed from the CBECS "Total Energy" load of 94.6 kBTU/ft^2/yr, the new total energy load, described as Design Energy becomes 77.5 kBTU/ft^2/yr. In this example, the combined HVAC&L loads of 71.2 kBTU/ft^2/yr now represents 91.9% of a building's total "Design Energy" load - dramatically increasing the sensitivity of LEED points to HVAC&L systems performance, and emphasizing the sensitivity of HVAC&L systems selection in estimating lifecycle cost.

It is interesting to note the impact regional variability in energy consumption can have on the sensitivity analysis for HVAC&L systems selection. Table 4 is similar to Table 3, but references regional energy averages obtained from the Building Energy Data Book (2004). The same energy breakdown performed with regional HVAC&L figures, produces significantly different results as HVAC&L loads only account for 50.9% of a buildings total energy load. This is significantly less that the 75.3% obtained from national data.

Distribution of Potential Energy Savings

While it is possible to achieve lower total energy use for a building by making adjustments to only one of the HVAC&L systems, this paper assumes that any reduction in a facility's total energy consumption will be obtained from proportional reductions in HVAC&L loads. For example, to achieve a 10% reduction in total energy load, all HVAC&L systems might be reduced by 2%. Alternatively HVAC performance may be left untouched and a 10% reduction may be achieved in lighting efficiency improvements alone.

The potential for total energy savings also varies dependent upon the building systems being evaluated. Boilers for example tend to perform at relatively high levels of thermal efficiency ranging from 85-95% dependent upon the make and manufacturer. Chillers in contrast have a wide range of efficiency levels dependent upon the system type (water or air cooled), the type (screw or centrifugal) , and the make and manufacture.

Variable frequency fans which are used to ventilate a building represent the “V” in HVAC and consist of an electric motor paired with a speed controller. Fans perform almost identically across all manufacturers in terms of energy performance, and hence represent a very limited opportunity to realize any building energy savings (Culp, 2012). As such ventilation systems are considered a constant in this paper and not evaluated as a source of significant energy savings.

In contrast, lighting systems may range from low performing incandescent fixtures, to high efficiency fluorescent and LED luminaires. Accordingly fixture and luminaire selection can provide significant lifecycle saving to owner groups and merit critical evaluation.. As is argued in this paper, the selection of HVAC systems and their associated energy saving profiles is a result of the owners capital investment profile and lifecycle target objectives.

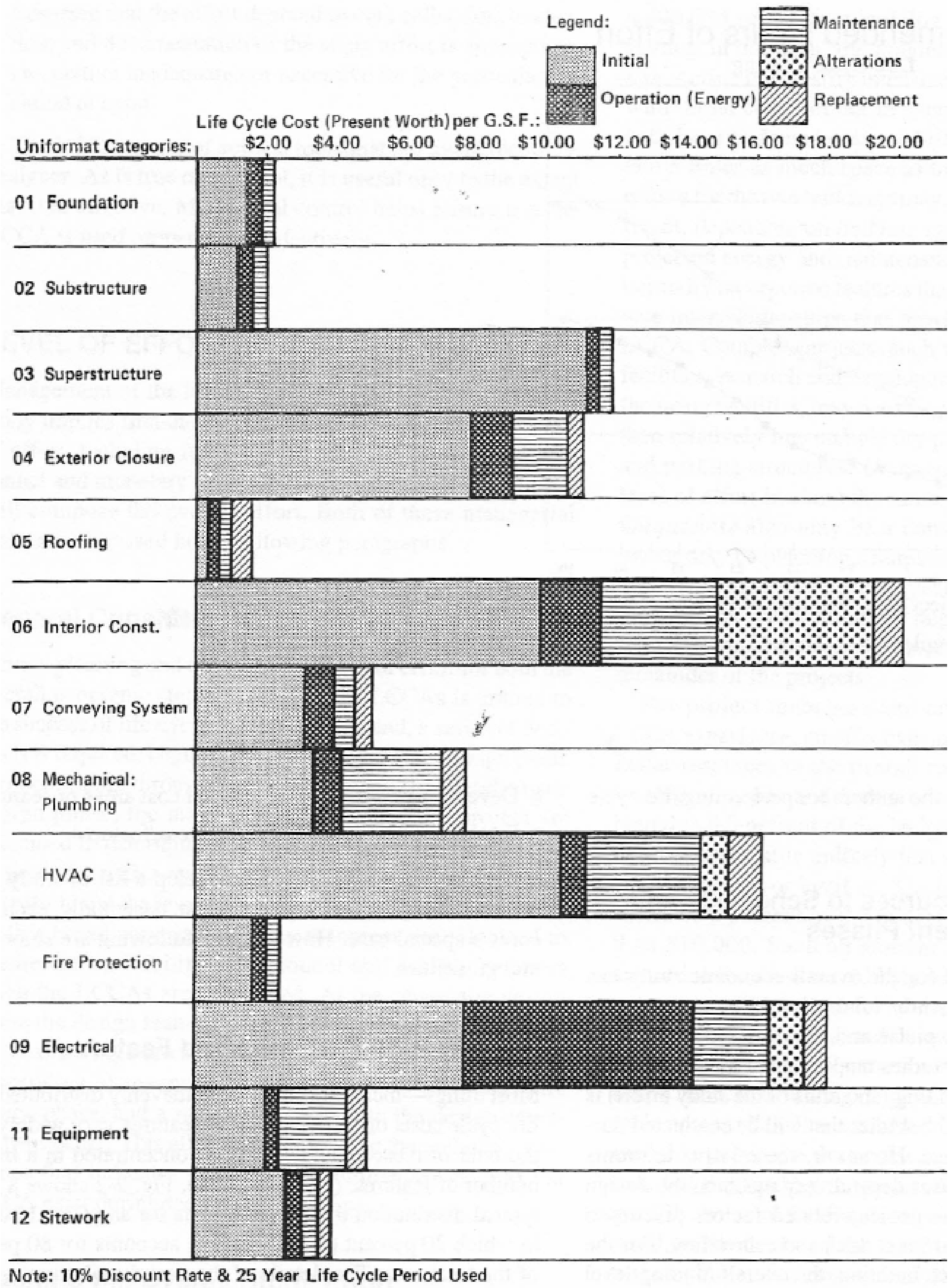


Figure 21. Lifecycle cost distribution (Kirk and Dell'Isolla, 1995)

Determining HVAC&L System Energy Cost

HVAC&L Systems Purchase and Installation Cost

Figure 21 illustrates the significance of HVAC&L costs. When considered together, they represent more than twice the initial and lifecycle cost of any other construction expense. Because pricing for large HVAC&L systems are typically provided as project specific quotes, manufacturers of competing products were contacted to obtain approximate pricing. A preliminary review of the R.S. Means pricing catalog suggests variations in regional installation cost are relatively small when compared to the purchase cost of the system. For the purpose of this study +10% of purchase cost will be used to approximate system installation costs.

Additionally although many competing HVAC&L systems may have similar performance specifications, other factors, not considered in this report may impact total ownership cost, such as the size of the necessary operating and maintenance staff, anticipated service and repair costs, and anticipated useful life (beyond the ten year scope of this study). Factors that do not affect system cost but do influence an owner's decision to purchase one system over another include reliability reports, customer service, and the sophistication of system controls necessary maximize user comfort.

HVAC&L Energy Efficiency Factors

In order to compare the energy performance of competing systems, an efficiency factor has to be introduced into the cost analysis to determine the proportional energy savings attributable to various systems. The ability to determine the energy savings between two different systems allows building owners to assign a dollar value to potential savings. Future savings can be projected for a 10 year warranty period and discounted to provide a present worth comparison between operational cost and first cost. Several equipment performance metrics exist to address the efficiency ratings of various types of equipment:

- Heating: There is currently no absolute standard to quantify boiler efficiency. Two dominant metrics, combustion efficiency, and thermal efficiency are typically referenced for commercial grade boilers with a capacity over 300,000 BTU/h (Consortium for Energy Efficiency (CEE), 2011).
    - Combustion Efficiency (CE): Measures the ability of the boiler to efficiently burn fuel, and equals 100 percent minus the percentage of fuel energy lost in the exhaust gases (i.e. flue loss).
    - Thermal Efficiency (TE): Is the dominant industry metric and measures the ratio of the heat energy output to the heat energy input, exclusive of equipment or "jacket" losses, and can be considered combustion efficiency minus equipment losses.
- Cooling: The Integrated Energy Efficiency Ratio (IEER) was developed by the Air Conditioning, Heating and Refrigeration Institute (AHRI) to rate the efficiency of commercial air cooled unitary chillers. IEER is a weighted average of the unit's efficiency at four load points; 100%, 75%, 50% and 25% of full cooling capacity.

The higher a systems IEER value, the better its energy performance. kW/Ton is the standard efficiency rating for water cooled chillers (Florida DMS, 2001).

- Lighting: Luminaire Efficacy Rating (LER) or Efficacy is expressed in lumens per watt (LPW or lm/W). To determine a system's efficacy, divide its lumen output by its rated input wattage (Fuller, 2010).

HVAC&L Size Factors

Figure 22 provides an example of rules of thumb parameters that can be used to obtain approximate BTU sizing for heating systems (boilers), and cooling systems (chillers). Based on the below information, designers can approximate that a 100,000 ft^2 Outpatient facility will require approximately a 200 ton chiller and boiler system, and proceed to solicit manufacturer pricing for appropriately sized systems.

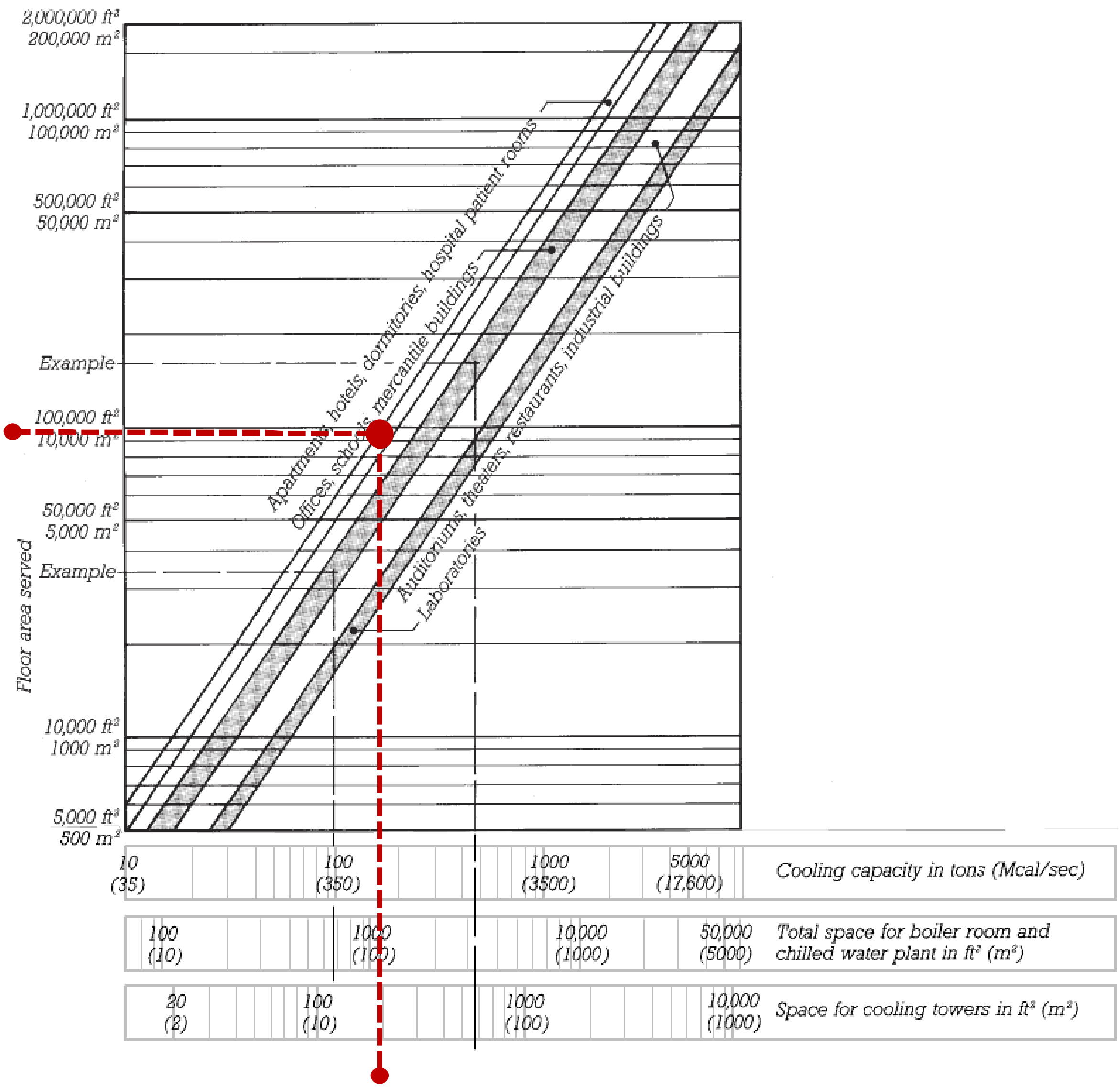


Figure 22. Sizing for major heating and cooling equipment (Allen and Iano, 2002)

Commercial Packaged Boilers

A commercial packaged boiler is composed of a tank (or water tubes), heat exchangers, fuel burners, exhaust vents and controls. Conventional boilers are inexpensive to manufacture and purchase but have sub optimal performance, while high efficiency boilers are typically more expensive due to their corrosion-resistant materials, improved insulation, and more sophisticated controls. Other advantages of efficiency systems include smaller footprints, reduced operation and maintenance costs, and improved safety, however; as indicated in Figures 23 and 24, the price of such units may be more than 50% greater than that of a standard efficiency unit (CEE, 2011). Boiler price estimates for this application were obtained from Burnham Commercial Boilers; see Appendix 2 for product specifications.

Commercial boilers can be grouped into three efficiency breakpoints (CEE, 2011):

1. Conventional boilers: Conventional systems are widely employed in the industry due to their low purchase and installation costs. Conventional systems typically operate at an efficiency of 80-83%.
2. Mid Efficiency Boilers: Mid efficiency systems operate between 83-88%, and are experiencing increasing market share as a result of their reduced operating costs.
3. Condensing boilers: Condensing boilers operate at efficiencies greater than 88%, but typically perform at efficiencies greater than 90%. Condensing boilers are typically 60% more expensive than conventional boilers.

Boiler Type	300,000 Btuh	Boiler Size 500,000 Btuh	1,000,000 Btuh
Atmospheric	1.0	1.2	1.7
Power Burner	1.2	1.9	2.8
Full Condensing	3.0	3.6	4.8

Figure 23. Ratios of boiler price compared to base price of conventional atmospheric boiler (Energy and Environmental Analysis (EEA, 2006)

System Type	Installed Cost of System	Annual Energy Consumption (Therm Eq.)	Energy Cost	Maintenance Cost	Net Present Cost	Net Present Cost Compared to Conventional Gas Boiler
Condensing Gas Boiler	$304,015	197,586	$1,446,342	$102,947	$1,853,304	($397,026)
Conventional Gas Boiler	$246,450	262,670	$1,935,248	$68,631	$2,250,329	-

Figure 24. Cost comparison of boiler efficiency levels (EEA, 2006).

Analysis | Heating Cost for Commercial Packaged Boilers

We can determine that the heating load of a hospital per the following method:

1. Identify the target LEED point total 1-19.
    a. Example: Assume a target value of 12 LEED EA1 points.
2. Use Table 1, to obtain the kBTU/ft^2/yr value.
    a. Table 1 indicates a maximum value of 184.14 kBTU/ft^2/yr in order to achieve 12 LEED points.
3. Multiply this value times the size of the facility being considered.
    a. Assume we are considering building a 100,000 s.f. facility
    b. 100,000 s.f. x 184.14 kBTU/ft^2/yr = 18,414,000 kBTU/yr
4. Utilizing table 4, multiply this value times the systems percentage of the facility's overall energy consumption. The result is the maximum kBTU allowed to be consumed by a given system per year.
    a. Assume we want to identify the maximum energy consumption of the heating system. Per Table 4, heating accounts for 40.3% of an outpatient facility's annual energy use.
    b. 18,414,000 kBTU/yr x 40.3% = 7,415,318 k BTU/yr
5. Since Boilers systems typically operate on natural gas due to its low cost (CEE, 2011). It is necessary to convert the annual kBTU/yr load into Therms, the standard billable unit of natural gas (1 Therm = 100,000 BTU).
    a. 7,415,318 kBTU/yr x 1000 BTU/100,000 BTU/Therm = 74,153 Therms

6. Efficiency Factor: The potential energy savings of a given Boiler is provided by the following general formula: Heating Capacity = Energy Demand x [(1-Annual Fuel Utilization Efficiency (AFUE) Index) + 1]. For boilers with a AFUE of 80% the efficiency factor is as follows:
   a. 74,153 Therms x [(1-.80)+1] = 88,984 Therms
7. 88,984 Therms x $1.10 (Center Point Energy) = $97,882 / year
   a. First cost | Boiler purchase and installation cost
   b. System cost per manufacturer quote: Assume $500,000
   c. System installation cost: +10% = $50,000
   d. First cost = $550,000

Findings | Heating Cost

Figure 25 is a summary of the framework utilized to determine operating cost and first costs for heating systems. In this example three boilers of varying levels of efficiency were selected for a preliminary analysis:

- Burnham Series 3
- Burnham Series 4S 4-Pass
- Burnham Low NOx Boiler

First cost and performance parameters were obtained from Burnham Commercial Boilers (Davis, 2012); and regionally specific energy costs obtained from CenterPoint Energy in Houston (CenterPoint, 2012) to estimate operating cost. First cost, annual operating cost, and the discounted total cost for each system was plotted and compared:

- First costs increased with boiler efficiency
- Annual cost decreased with boiler efficiency
- Notably, the discounted total cost between the lowest and mid-priced boilers for the ten year analysis were lower than that of the most efficient boiler.
- The discounted total cost of the low and mid-priced systems were comparable.
- Because the low priced system produced the lowest total cost of ownership, an owner may opt to install least expensive (and efficient) system.

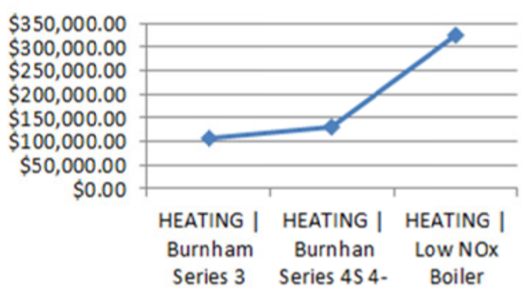
The data suggests that the reason for this finding is that boilers in general typically perform at high efficiencies; so slight variations in operating performance between individual systems may not produce enough of a lifecycle savings to offset the significant increase in first cost associated with high performance boilers.

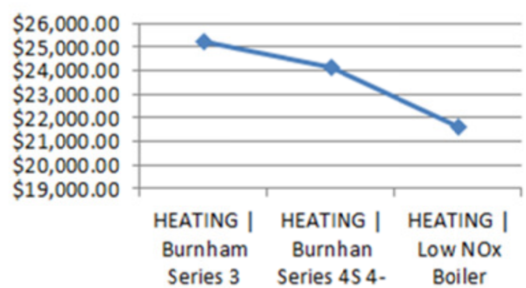
HEATING | Burnham Series 3		
Percent of total building energy load:	21.11%	
Heating Operational Cost		
Heating Load	3,887,400	kBtu/yr
Conversion	38,874.00	Therms
Efficiency factor	80%	TE
Energy Multiplier	1.20	
Billable Energy	46,648.80	Therms
Natural Gas Price	$0.54	/Therm
Operating Cost	$25,190.35	/yr
Heating First Cost		
Purchase Cost	$98,000.00	
InstallationCost	$9,800.00	
P&I Cost	$107,800.00	

HEATING | Burnhan Series 4S 4-Pass		
Percent of total building energy load:	21.11%	
Heating Operational Cost		
Heating Load	3,887,400	kBtu/yr
Conversion	38,874.00	Therms
Efficiency factor	85%	TE
Energy Multiplier	1.15	
Billable Energy	44,705.10	Therms
Natural Gas Price	$0.54	/Therm
Operating Cost	$24,140.75	/yr
Heating First Cost		
Purchase Cost	$120,000.00	
InstallationCost	$12,000.00	
P&I Cost	$132,000.00	

HEATING | Low NOx Boiler		
Percent of total building energy load:	21.11%	
Heating Operational Cost		
Heating Load	3,887,400	kBtu/yr
Conversion	38,874.00	Therms
Efficiency factor	97%	TE
Energy Multiplier	1.03	
Billable Energy	40,040.22	Therms
Natural Gas Price	$0.54	/Therm
Operating Cost	$21,621.72	/yr
Heating First Cost		
Purchase Cost	$294,000.00	
Installation Cost	$29,400.00	
P&I Cost	$323,400.00	

	Operating Cost	First Cost	Discounted 10YR Cost	Discounted Total Cost
HEATING | Burnham Series 3	$25,190.35	$107,800.00	$154,783.81	$262,583.81
HEATING | Burnhan Series 4S 4-Pass	$24,140.75	$132,000.00	$148,334.48	$280,334.48
HEATING | Low NOx Boiler	$21,621.72	$323,400.00	$132,856.10	$456,256.10





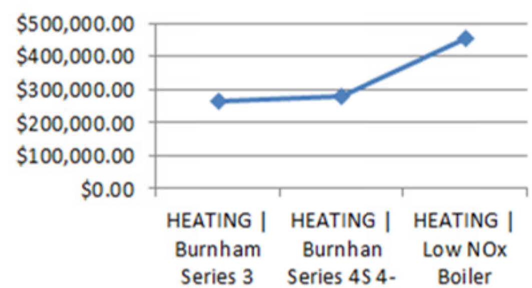


Figure 25. Framework for comparing heating systems performance

Commercial Chillers

Chillers provide the cooling for commercial facilities and are composed of a condenser, an evaporator (comprised of coiled tubes), and a compressor (typically an electric motor). The refrigerant cycle consists of two significant processes: A liquid refrigerant evaporating into its gaseous state (at a low temperature) to absorb heat from a system, and then being compressed back into its liquid state to repeat the cycle (American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE), 2007).

Commercial chillers are typically categorized into two categories - air and water cooled systems. The refrigeration cycle is identical for booth; only the medium used to transfer latent heat into the atmosphere varies.

Air cooled: Air-cooled systems that function without any condenser water pumps or water cooling towers typically require lower purchase, installation, and maintenance costs, and do not require mechanical rooms. Since wet surfaces transfer heat more efficiently than dry surfaces, air-cooled chillers consume about 10% more power than water-cooled units do.

Water cooled: Water-cooled chillers use water, rather than air, to cool the refrigerant. The latent heat exiting the condensers is cooled, in many cases via cooling towers. The cooled water exiting the towers then enters the condenser and the heat removal cycle is repeated. The large refrigerating capacities and high efficiencies achievable with water-cooled chillers make them typical for large commercial applications.

Figures 26 illustrate the range in three water cooled chiller systems based on lifecycle cost. Figure 27 illustrates the range in minimum levels of energy efficiency based on system type. See Appendix 3 for product specifications.

Cost Category	Option #1	Option #2	Option #3
Chiller Bid Price (both chillers)	$451,004.00	$321,475.45	$395,338.00
Extended Warranty & Service	$54,948.00	$60,960.00	$47,160.00
Total First Cost (bid price + warranty)*	$505,952.00	$382,435.00	$442,498.00
Annual Operating Cost	$111,809.41	$147,401.37	$106,100.40
Life-Cycle Operating Cost (present value)	$1,946,601.86	$2,566,257.84	$1,847,207.94
Total 25-Year Life-Cycle Cost (present value)**	$2,452,553.86	$2,948,693.29	$2,289,705.94

**The Total First Cost = Chiller Bid Price + 5-Year Extended Warranty & Service*
***The Total 25-Year Life-Cycle Cost = Total First Cost + Life-Cycle Operating Cost*

Figure 26. First cost and annual operating cost comparisons for water cooled chillers of competing efficiency (Florida Department of Management Services, 2001)

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[a]
Air Conditioners, air cooled	<65,000 Btu/h[c]	All	Split System	13.0 SEER
			Single Package	13.0 SEER
Through-the-wall air cooled	≤30,000 Btu/h[c]	All	Split System	12.0 SEER
			Single Package	12.0 SEER
Small-duct high velocity, air cooled	<65,000 Btu/h[c]	All	Split System	10.0 SEER
Air Conditioners, Air Cooled	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 1.4 IEER
		All other	Split System and Single Package	11.0 EER 11.2 IEER
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER
		All other	Split System and Single Package	10.8 EER 11.0 IEER
	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 10.1 IEER
		All other	Split System and Single Package	9.8 EER 9.9 IEER
	≥760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 9.8 IEER
		All other	Split System and Single Package	9.5 EER 9.6 IEER
Air Conditioners, Water and Evaporatively Cooled	< 65,000 Btu/h	All	Split System and Single Package	12.1 EER 12.3 IEER
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER 11.7 IEER
		All other	Split System and Single Package	11.3 EER 11.5 IEER
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER
		All other	Split System and Single Package	10.8 EER 11.0 IEER
	≥240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER
		All other	Split System and Single Package	10.8 EER 10.9 IEER

Figure 27. Air Conditioning system minimum efficiency performance (American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE), 2007)

Analysis | Air Conditioning Cost

From Table 1 we can determine that the cooling load of a hospital per the following process:

1. Identify the target LEED point total 1-19.
    a. Example: Assume a target value of 12 LEED EA1 points.
2. Use Table 1, to obtain the kBTU/ft^2/yr value.
    a. Table 1 indicates a maximum of 184.14 kBTU/ft^2/yr in order to achieve 12 LEED points.
3. Multiply this value times the size of the facility being considered.
    a. Assume we are considering building a 100,000 s.f. facility
    b. 100,000 s.f. x 184.14 kBTU/ft^2/yr = 18,414,000 kBTU/yr
4. Multiply this value times the systems percentage of the facility's overall energy consumption as defined per Table 4. The result is the maximum kBTU allowed to be consumed by a given system per year.
    a. Assume we want to identify the maximum energy consumption of the cooling system. Per Table 4, cooling accounts for 7.2% of an outpatient facility's annual energy use.
    b. 18,414,000 kBTU/yr x 7.2% = 1,401,488 kBTU/yr

5. Efficiency Factor | The potential energy savings of a given HVAC system is provided by the following general formula:
    a. Cooling Capacity / IEER /1000 Annual Cooling Hours = kWh (Example: for 180,000 BTUH, 12.1 IEER unit = 180,000 / 12.1 / 1000 = 14.88 kW)
    b. 1,401,488 kBTU/yr ÷ 12.1 (IEER) ÷ 1000 = 115.8 kBTU/yr
    c. 115.8 kBTU/yr x 8766 hours/year = 1,015,326 kWh
    d. 1,015,326 kWh x $.10/kWh = $101,532.62
6. First cost | Chiller purchase and installation cost
    a. System cost per manufacturer quote: Assume $800,000
    b. System installation cost: +10% = $80,000
    c. First cost = $880,000

Findings | Cooling Cost

Figure 28 is a summary of the framework utilized to determine operating cost and first costs for cooling systems. In this example three chillers of varying levels of efficiency were selected for a preliminary analysis:

- Carrier 30XA
- Carrier 19XRV
- Carrier 23XRV

First cost and performance parameters were obtained from Carrier Commercial Chillers (Lewis, 2012); and regionally specific energy costs obtained from CenterPoint Energy in Houston (CenterPoint, 2012) to estimate operating cost. First cost, annual operating cost, and the discounted total cost for each system was graphically plotted and compared:

- First costs increased with chiller efficiency
- Annual cost decreased with chiller efficiency
- The discounted total cost decreased with system efficiency.
- Notably, the discounted total costs of the mid and high-priced systems were comparable.
- Because the mid-priced system produced the lowest total cost of ownership, owners may opt to install the mid-priced system to reduce initial capital expenditures.

COOLING | Carrier 30XA		
Percent of total building energy load:	14.84%	
Cooling Operational Cost		
Cooling Load	2,732,400	kBtu/yr
Efficiency factor	14.40	IEER
Billable Energy	189.75	kWh
Electricity Price	$0.10	
Operating Cost	$166,334.85	/yr
Cooling First Cost		
Purchase Cost	$210,000.00	
InstallationCost	$21,000.00	
P&I Cost	$231,000.00	

COOLING | Carrier 19XRV		
Percent of total building energy load:	14.84%	
Cooling Operational Cost		
Cooling Load	2,732,400	kBtu/yr
Efficiency factor	26.60	IEER
Billable Energy	102.72	kWh
Electricity Price	$0.10	
Operating Cost	$90,045.93	/yr
Cooling First Cost		
Purchase Cost	$360,000.00	
InstallationCost	$36,000.00	
P&I Cost	$396,000.00	

COOLING | Carrier 23XRV		
Percent of total building energy load:	14.84%	
Cooling Operational Cost		
Cooling Load	2,732,400	kBtu/yr
Efficiency factor	40.20	IEER
Billable Energy	67.97	kWh
Electricity Price	$0.10	
Operating Cost	$59,582.63	/yr
Cooling First Cost		
Purchase Cost	$540,000.00	
InstallationCost	$54,000.00	
P&I Cost	$594,000.00	

	Operating Cost	First Cost	Discounted 10YR Cost	Discounted Total Cost
COOLING | Carrier 30XA	$166,334.85	$231,000.00	$1,022,055.65	$1,253,055.65
COOLING | Carrier 19XRV	$90,045.93	$396,000.00	$553,293.28	$949,293.28
COOLING | Carrier 23XRV	$59,582.63	$594,000.00	$366,109.49	$960,109.49

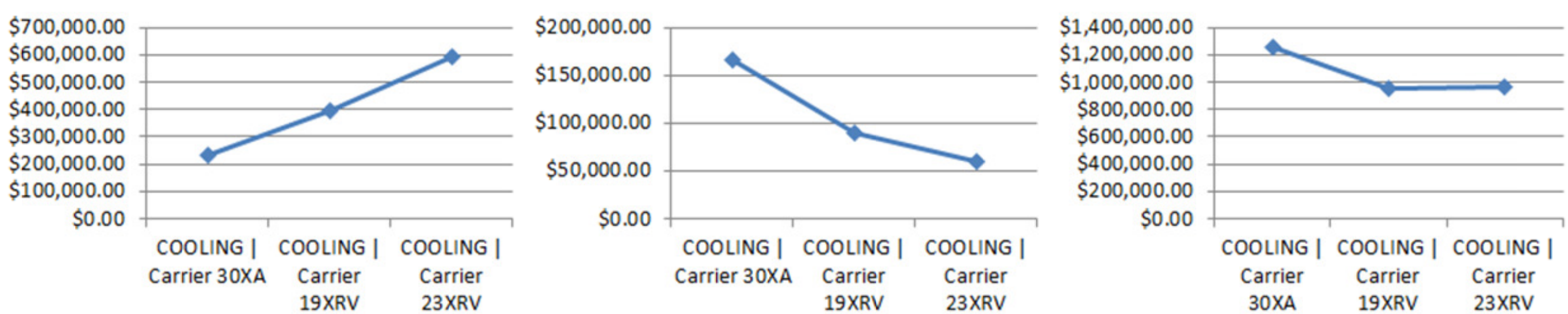


Figure 28. Framework for comparing cooling systems performance

Luminaires

Lighting systems vary significantly in terms of first cost, lamp life, luminescence, and efficacy. Figure 29 highlights some of the performance characteristics of commonly used commercial luminaires ranging from72 lumens per watt (lm/W) to 103 lm/W. For the purpose of this study we shall consider low (72 lm/W, $5.28), medium (87 lm/W, $6.29), and high (103 lm/W, $6.99) efficacy fixtures to compare a range of performance characteristics.

Ballast	Lamp Selection				
	F32T8 Standard	F32T8 Premium	F32T8 High Performance	F28T5 Standard	F28T5 Premium
Generic Standard Instant Start (59 W, 0.87 BF-T8/1.0 T5)	77	80	87	NA	NA
Standard Instant Start Low Light Level (54 W, 0.78 BF)	75	78	85	NA	NA
Standard Instant Start High Light Level (74 W, 1.15 BF)	81	84	92	NA	NA
Standard Program Start Normal Light Level (60 W, 0.88 BF)	78	82	88	95	100
Program Start Low Light Level (56 W, 0.78 BF)	73	75	82	NA	NA
Dimming Rapid Start (64 W max, 0.88 BF-T8/1.0 T5)	72	75	81	NA	NA
High-Performance Normal Light Level (55 W, 0.88 BF-T8/ 1.0 T5)	85	90	95	95	100
High-Performance Low Light Level (48 W, 0.78 BF)	85	88	96	93	98
High-Performance High Light Level (70 W, 1.15 BF)	86	89	97	98	103
High-Performance Dimming, Step and Continuous (54 W, 0.87 BF-T8/1.0 T5)	78	81	97	90	95

Figure 29. Efficacy values for different linear fluorescent lamp/ballast combinations (ASHRAE, 2012)

Analysis | Lighting Cost

1. From Table 1 we can determine that the lighting load of a hospital per the following process.
2. Use Table 1, to obtain the kBTU/ft^2/yr value.
    a. Table 1 indicates a maximum of 184.14 kBTU/ft^2/yr in order to achieve 12 LEED points.
3. Multiply this value times the size of the facility being considered = 100,000 ft^2
    a. 100,000 s.f. x 184.14 kBTU/ft^2/yr = 18,414,000 kBTU/yr
    b. Multiply this value times the systems percentage of the facility's overall energy consumption as defined per Table 4. The result is the maximum kBTU allowed to be consumed by a given system per year.
4. Assume we want to identify the maximum energy consumption of the lighting system. Per Table 4, lighting accounts for 23.89% of an outpatient facility's annual energy use.
    a. 18,414,000 kBTU/yr x 23.89% = 4,399,104 kBTU/yr
5. Because Lighting systems typically operate on electricity, it is necessary to convert the annual kBTU/yr load into kWh, the standard billable unit of electricity by first converting annual BTU into hourly BTU:
    a. There are 8766 hours in one year
    b. 4,399,104 kBTU/yr ÷ 8766 = 501.84 kBTU/hr
6. Thermal energy (BTU) must now be converted into its electrical unit of equivalency kWh)

a. 1 BTU = 0.00029307107017 kWh ($2.93x10^{-4}$)

b. 501.84 kBTU/hr x 1000 = 501,840 BTU/hr

c. 501,840 BTU/hr x 0.00029307107017 kWh = 147.1 kWh

7. Efficiency Factor | The potential energy savings of a given luminaire is provided by the following formula: Energy Demand = Energy x [(1- Luminaire Efficacy Rating (LER) + 1]. For T8 luminaires with a LER of 15% the efficiency factor is as follows:

   a. 147.1 kWh x 1.85 [(1-.15)+1]= 272.1 kWh

   b. 272.1 kWh x 8766 hour/yr x $.10 / kWh = $238,553.54 / year

8. First cost | The cost of luminaire installation:

   a. Luminaire coverage: T8 Fluorescents = (15'x15') 225 ft^2

   b. Building size = 100,000 ft^2

   c. Number of required fixtures = 100,000 ft^2 / 225 ft^2 = 444 fixtures

   d. Price per fixture = $180

   e. Lighting initial cost = $80,000

Findings | Lighting

Figure 30 is a summary of the framework utilized to determine operating cost and first costs for lighting systems. In this example three chillers of varying levels of efficiency were selected for a preliminary analysis:

- F32T8 Fixtures
- F32T8 High Performance Fixtures
- F28T5 Fixtures

First cost and performance parameters were obtained from internet vendors; and regionally specific energy costs obtained from CenterPoint Energy in Houston (CenterPoint, 2012) to estimate operating cost. First cost, annual operating cost, and the discounted total cost for each system was graphically plotted and compared:

- First costs increased with lighting efficiency
- Annual cost decreased with lighting efficiency
- The discounted total cost decreased with system efficiency.
- Notably, the discounted total costs of the mid and high-priced systems were comparable.
- Because the high-priced system produced the lowest total cost of ownership, owners may opt to install the mid-priced system.

The data suggests that the reason for this finding is that light fixtures differ significantly in terms of efficiency, but are relatively comparable in terms of first costs (especially when compared to HVAC equipment). Accordingly, lifecycle savings resulting from variations in operating performance are ample enough to offset first costs.

LIGHTING | F32T8		
Percent of total building energy load:	8.10%	
Lighting Operational Cost		
Lighting Load	1,491,600	kBtu/yr
BTU - kWh Conversion	50	kWh
Luminaire efficiency rating	72%	lm/W
Billable Energy	63.83	kWh
Electricity Price	$0.10	
Operating Cost	$55,954.54	
Lighting First Cost		
Liminaire Coverag	220.00	ft²
Req.No. of Fixtures	455	
Purchase Cost	$70.00	
Installation Cost	$7.00	
P&I Cost	$35,000.00	

LIGHTING | F32T8 High Performance		
Percent of total building energy load:	8.10%	
Lighting Operational Cost		
Lighting Load	1,491,600	kBtu/yr
BTU - kWh Conversion	50	kWh
Luminaire efficiency rating	86%	lm/W
Billable Energy	56.85	kWh
Electricity Price	$0.10	
Operating Cost	$49,834.51	
Lighting First Cost		
Liminaire Coverag	220.00	ft²
Req.No. of Fixtures	455	
Purchase Cost	$78.00	
Installation Cost	$7.80	
P&I Cost	$39,000.00	

LIGHTING | F28T5		
Percent of total building energy load:	8.10%	
Lighting Operational Cost		
Lighting Load	1,491,600	kBtu/yr
BTU - kWh Conversion	50	kWh
Luminaire efficiency rating	100%	lm/W
Billable Energy	49.87	kWh
Electricity Price	$0.10	
Operating Cost	$43,714.48	
Lighting First Cost		
Liminaire Coverag	220.00	ft²
Req.No. of Fixtures	455	
Purchase Cost	$102.00	
Installation Cost	$10.20	
P&I Cost	$51,000.00	

	Operating Cost	First Cost	Discounted 10YR Cost	Discounted Total Cost
LIGHTING | F32T8	$55,954.54	$35,000.00	$343,816.40	$378,816.40
LIGHTING | F32T8 High Performance	$49,834.51	$39,000.00	$306,211.48	$345,211.48
LIGHTING | F28T5	$43,714.48	$51,000.00	$268,606.56	$319,606.56

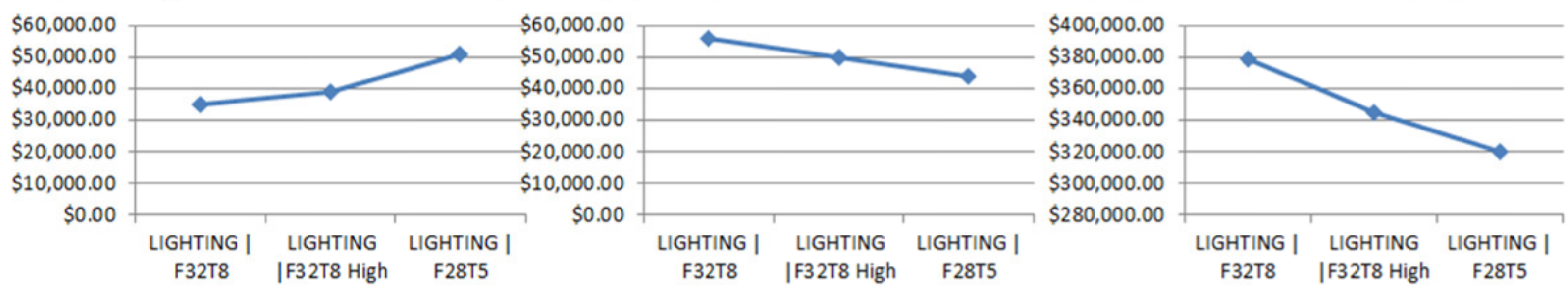


Figure 30. Framework for comparing lighting systems performance

First Cost | Operational Cost

Figures 31, 32, and 33 summarize the first cost, annual cost, and total cost of the previous HVAC&L analysis. It is interesting to note that for each system, the total cost of ownership suggested a different level of recommended systems of varying levels of performance:

- Heating: Low Performer – Burnham Series 3 Boiler (Figure 31C)
- Cooling: Mid Performer – Carrier 19XRV Chiller (Figure 32C)
- Lighting: High Performer – F28T5 Fixture (Figure 33C)

Because every project is unique, no general conclusion can be made about the appropriateness of these specific systems for any particular project. What the researcher can conclude however, is than the practice of selecting the highest performing system under the assumption that it will result in the lowest total cost of ownership is inappropriate. And basing systems selection exclusively on the criteria of maximing energy savings, particularly when pursing LEED certifications, may not bein the best interest of the owner.

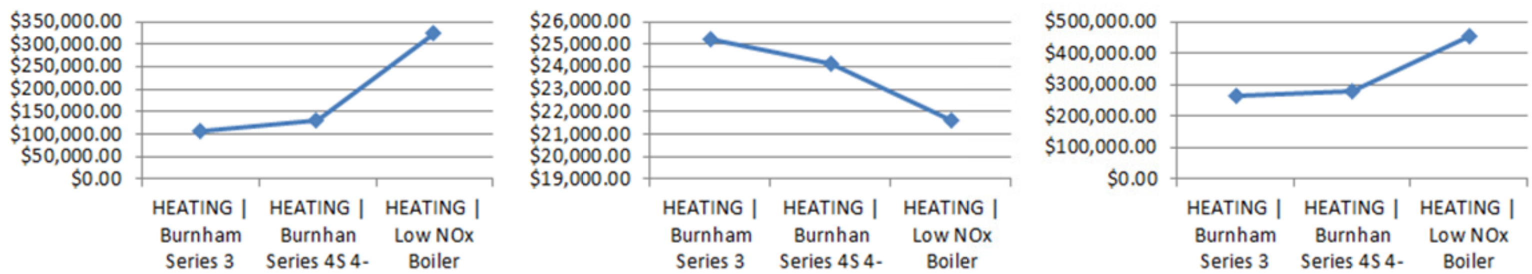


Figure 31. Boiler: (A). First cost. (B) Annual cost. (C) Lifecycle cost.

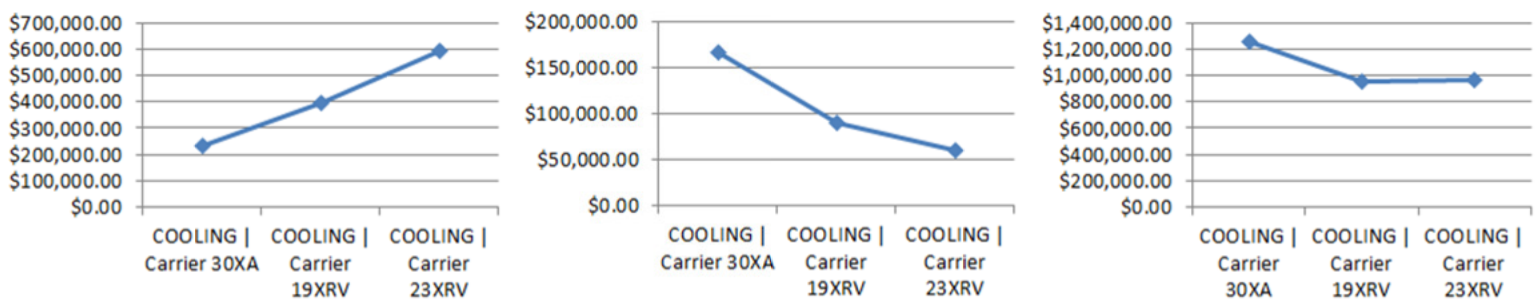


Figure 32. Chiller: (A). First cost. (B) Annual cost. (C) Lifecycle cost.

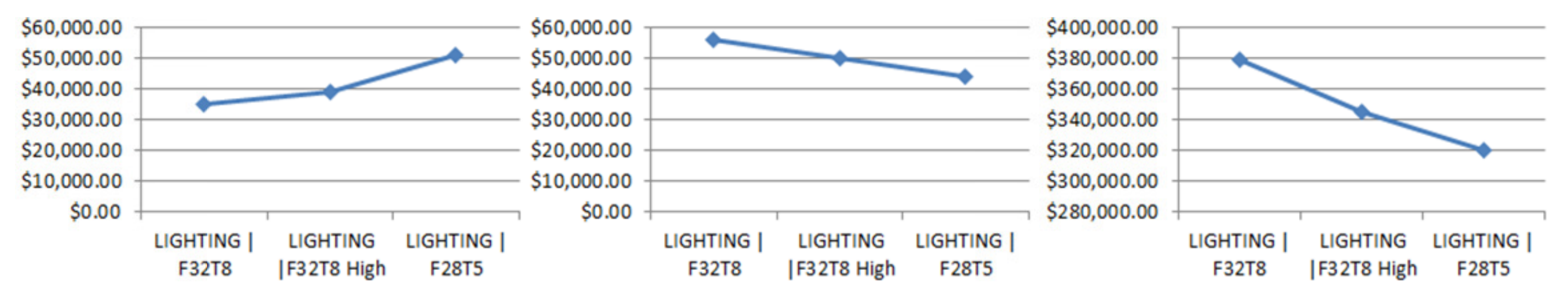


Figure 33. Lighting: (A). First cost. (B) Annual cost. (C) Lifecycle cost.

Table 5 illustrates the maximum difference in total ownership cost if the owner were to select all the lowest performing HVAC&L systems as might randomly occur if the owner did not perform a life cycle cost analysis; compared to a facility that included all the highest performing systems based on life cycle cost decisions. What Table 5 illustrates is the potential range in lifecycle savings that can be achieved when estimating ownership costs.

The worst HVAC&L systems selection produced a total ownership cost of $2,088,128, while the best system selection produced a total ownership cost of $1,531,484. Resulting in a potential savings to the owner of $556,645, or an internal rate of return of almost 27%.

Table 5. Summary of findings between low and high performing systems

HVAC&L |Low Performance		
Percent of total building energy load:		**51.00%**
Total Ownership Cost		
Heating Cost	$456,256.10	
CoolingCost	$1,253,055.65	
Lighting Cost	$378,816.40	
NPV	**$2,088,128.15**	/10 years
HVAC&L |High Performance		
Percent of total building energy load:		**51.00%**
Total Ownership Cost		
Heating Cost	$262,583.81	
CoolingCost	$949,293.28	
Lighting Cost	$319,606.56	
NPV	**$1,531,483.65**	/10 Years

CHAPTER V

CONCLUSIONS

One of the primary research objectives of this paper was to determine if a correlation existed between LEED building certifications and reduced ownership costs; and to what extent, if any, regional factors (including climate zone and energy cost) can produce variances in ownership costs. A significant finding of this paper is that regional factors can dramatically affect a building's system's required level of energy performance; and as a result, the national averages utilized to establish LEED EA1 thresholds do not reflect the cost particularities owners may encounter when developing in various climate zones. Accordingly the highest performing system, irrespective of cost, will not always provide the best return on investment.

For example, installing the highest performing water cooled chillers in a facility in Anchorage Alaska may not provide a reasonable return on investment because cooling days represent such a small percentage of climate zone 8's energy load. Similarly, investing in high performance condensing boilers in a region with low energy costs may not produce enough lifecycle savings to offset first costs. The framework introduced in this paper provides a method by which owner groups can make assessments regarding systems selection while demonstrating sensitivity to regional variables.

Another objective of this research was to identify variables that significantly impact facility performance, and to determine if whole building simulations are indeed necessary to predict energy lifecycle performance. As demonstrated, database lifecycle estimates provide historical and simulated energy information for all building programs in each climate zone and identifies which building systems consume the most energy in each climate zone. By utilizing this information in much the same way that construction estimators utilize historical costs to predict future costs, energy use intensities can be developed on a square foot basis and applied to an anticipated facilities for pro forma development.

The variability of system performance, climate, energy costs, etc. demonstrated in this research further strengthens the argument that assumptions based on national averages can misrepresent regional conditions. As such, each facility is a unique lifecycle cost problem with distinct variables for equipment, energy, and financing costs. Furthermore, because business priorities may vary for similar facilities even with the same organization, capital investments have to be considered within the context of the corporate objectives for each particular real estate asset.

Literature

Techniques utilized to perform an LCCA referenced in the literature review are the foundation upon which this research was established. However, the application of LCCA techniques on the question of sustainability certifications as discussed in this paper differs from the literature in four significant ways.

The literature regarding LCCAs supports a method of lifecycle analysis undertaken during the design phase. The author was not able to identify literature that supported an LCCA applied to a facility during the pro forma phase, and so the content of this paper explores a non-traditional application of LCCA described as database lifecycle estimating.

A review of sustainability literature produced numerous examples of authors suggesting that that achieving increasing levels of sustainability ratings will correlate with reduced operating costs. The reader is typically left under the impression that reduced operating costs will translate into reduced ownership cost. This study has demonstrated that this correlation does not necessarily exist.

The findings of this paper support the premise that a conflict of interest exists on the part of sustainable rating organizations. Organizations such as the USGBC require industry participation to exist, however cannot affirm findings that may suggest that achieving certain sustainability ratings may result in increase ownership costs. In this regard, the findings of this paper contradict the marketed perception that sustainability ratings will reduce ownership costs.

A review of the literature regarding project delivery systems indicated an institutionalized conflict of interests between owner objects, and the financial reward mechanisms of design and build teams. Emphasizing first cost as the dominate measure of project success motivates low cost system selection at the expense of increased total ownership cost. Despite the significant impact construction contracts can have on a facility's performance, this institutionalized misalignment of party interests does not seem to be recognized or articulated in the literature.

Major Findings

A summary of the major findings of this paper include the following:

- There is not a necessary correlation between a sustainability credential and lower lifecycle cost.
- The highest performing HVAC&L system irrespective of cost will not always provide the lowest cost of ownership or the best return on investment.
- Energy profiles obtained from energy use databases can be leveraged to provide operational estimates without the need for a building design, or the need to retain an A&E team.
- There is an inherent conflict of interest between a sustainable organization's need to perpetuate its rating system through industry participation, and full disclosure of the possible negative impact of building certification on total ownership cost.
- Capital investments must be considered within the framework of an organization's corporate goals and a facility's pro forma objectives. To best achieve owner objectives, LEED certification ratings should also be assessed within these parameters.
- Each facility is a unique lifecycle cost problem with distinct variables of analysis.

- Project delivery systems and the potential misalignment of party interests can have a significant negative impact on systems selection and the total cost of ownership.

Constraints

The chief constraint in the development of this paper is the professional limitation of the author. The need to determine if a correlation exists between LEED certification and reduced ownership cost established the strategic direction and logical structure for this research. However, with a background in Architecture, Construction Management and Land and Property Development, the author lacked the technical expertise in mechanical, electrical and plumbing (MEP) systems that could have benefited the development of the mathematical process used in this analysis. Accordingly, this research would profit from the review and critique of a licensed MEP engineering team with expertise in each of the respective HVAC&L systems considered.

Reflections

With the advantage of hindsight the author feels that this research would have benefited by the inclusion of a committee member in the College of Engineering with expertise in energy modeling and HVAC&L systems. Lacking this insight, soliciting the review of a professional engineering team would serve to add the expertise of real world practitioners to this research.

Recommendations

Because database lifecycle estimates are only approximations of anticipated future performance, this study would benefit from field verification of estimated performance in a real outpatient facility. Accordingly, a series of case studies that could be used to statistically quantify real world data and compare this information would benefit the research in two significant ways:

- First, a statistically significant case study would serve to verify that the logic employed in database lifecycle estimating is sound.
- Secondly, the data provided by real world data could serve to establish an anticipated level of accuracy of lifecycle database estimates.

Significance

The framework developed in this paper adds value to the user in two significant ways.

- Database lifecycle estimating demonstrates that there exists a multitude of possible system, location, and facility combinations that will impact the desirability of one particular capital investment over another. Accordingly, owners must be aware that the national energy averages commonly referenced by sustainable rating organizations, including LEED ignore the significant impact regional factors can have on system selection and can have a negative impact on total ownership cost.
- It has been demonstrated that contrary to common practice, it is possible for preliminary lifecycle estimates to be developed early in the predesign process,

providing critical information to early decision makers without the cost or time investment necessary to develop a building design or even retain an A&E team.

Further Study

In terms of point availability, LEED EA1 is the single most important credit category, accounting for a full 17% of the 110 available LEED points (USGBC, 2009). At the same time LEED EA1 still represents just one of the criteria used to determine a building's LEED rating. A continuing opportunity exists to further develop a database lifecycle estimate strategy for all credits in the LEED rating system. Providing a comprehensive estimating methodology for a project's potential LEED rating can provide significant value to owner groups interested in assessing the feasibility of certified, silver, gold and platinum ratings.

Future Project Delivery Systems

By quantifiably potential lifecycle savings to owner groups, the financial benefits of a lifecycle consultant, or Lifecycle Analyst (LA) integrated as an independent member of the construction contract can eliminate waste and streamline the design process. By incorporating a LA into the design and build team, owners can:

1. Form a more complete and accurate picture of the "total cost" of building construction AND ownership.

2. Leverage the Lifecycle Analyst's industry wide expertise to make more informed decisions regarding O&M considerations before the building is designed - rather than attempting to remediate issues after the building is constructed.
3. Reduce overall project costs while simultaneously improving quality.

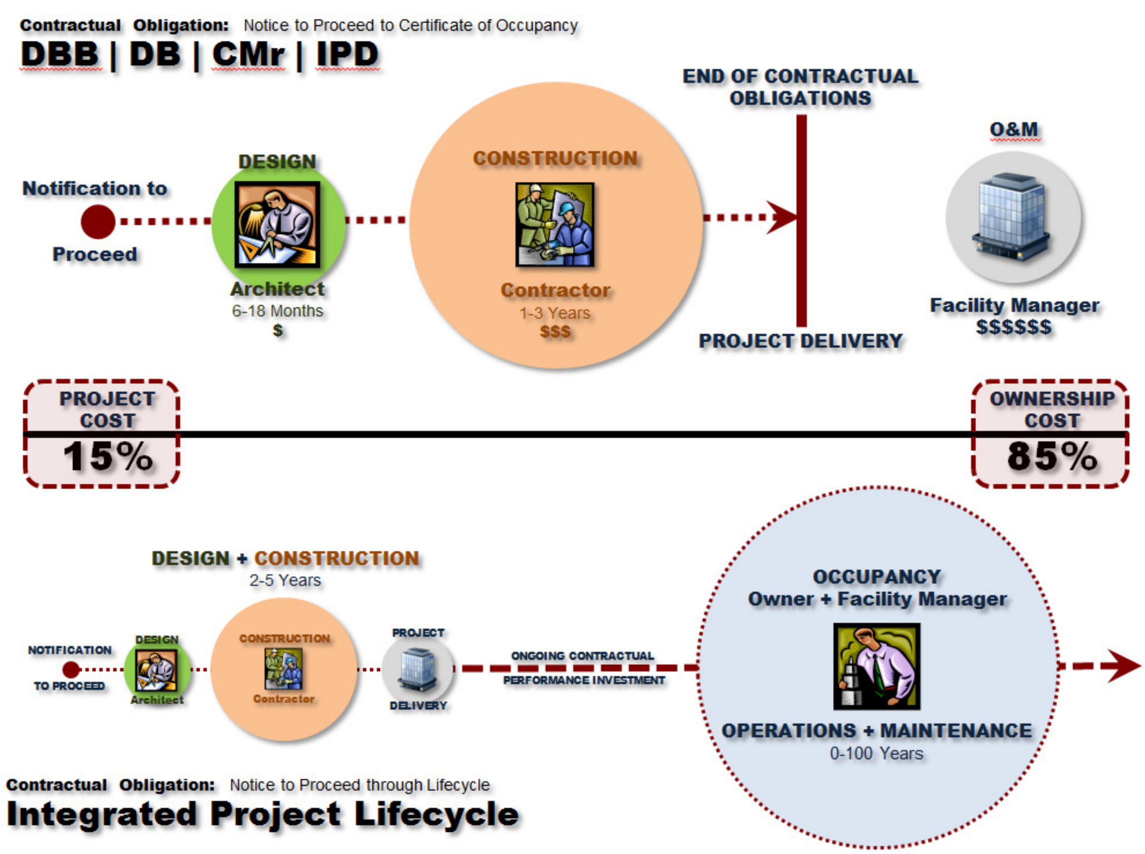


Figure 34. Project delivery comparison: Continuing lifecycle participation (Daniels 2012)

Because current project delivery methods terminate the design and build team's obligations at project delivery, these methods inadvertently incentive the first cost metric of lowest delivery cost. Opportunities exist to develop a modified project delivery method that creates a continuing investment on the part of the design build team by rewarding them for a facility's superior lifecycle performance (Figure 34). Because research has indicated that lifecycle cost are 5.5 times more significant than first cost, a delivery system such as Integrated Project Lifecycle (IPL) realigns consultant incentives to better achieve the owners long term facility objectives. Extending the contractual obligations of the design build team beyond project delivery in the form of shared performance rewards motivates the designer and builder to target long term facility performance (Figure 35).

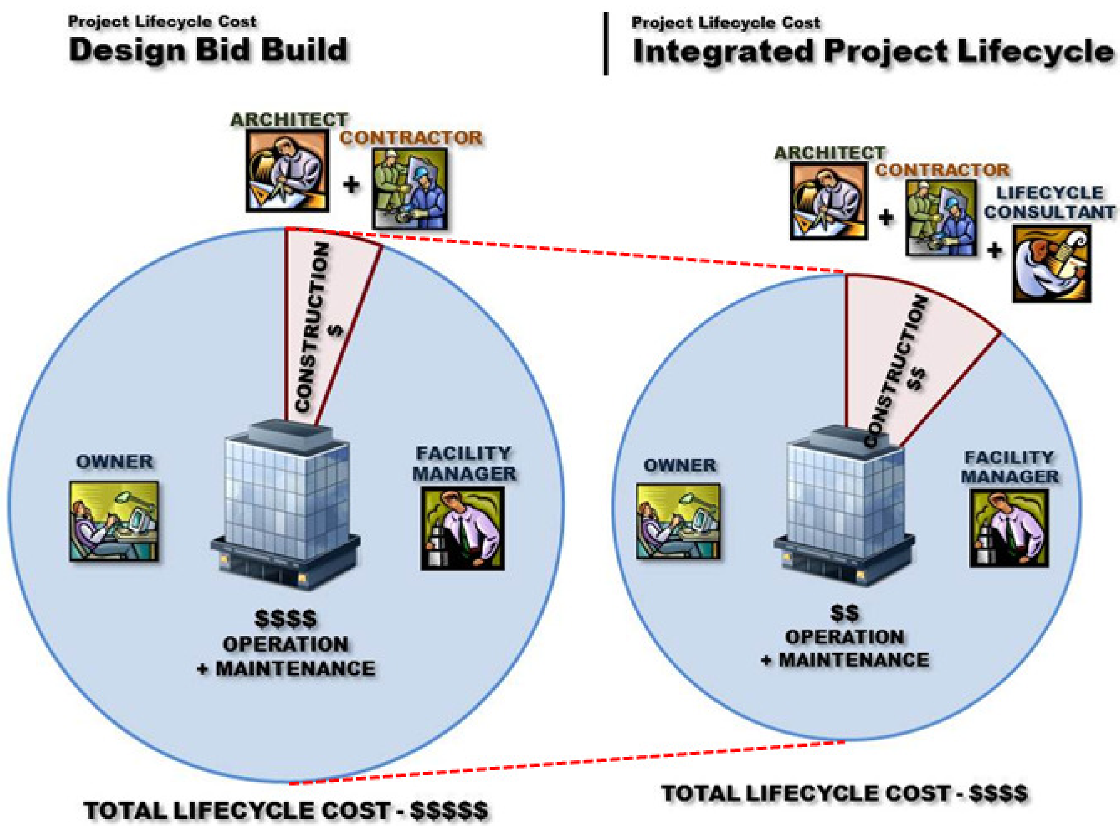


Figure 35. Project delivery comparison: Potential cost impact of an independent LCCA consultant on project delivery systems (Daniels, 2012)

Integrated Project Lifecycle

Like Integrated Project Delivery, Integrated Project Lifecycle creates a multiparty agreement between all members of the construction contract so that all design and construction decisions are vetted by each party. However, unlike IPD, IPL incentivizes the team to demonstrate tangible achievement of the owner's lifecycle objectives through the use of an independent Lifecycle Analysis retained as an indented advisor and auditor of design and construction decisions (Figure 36).

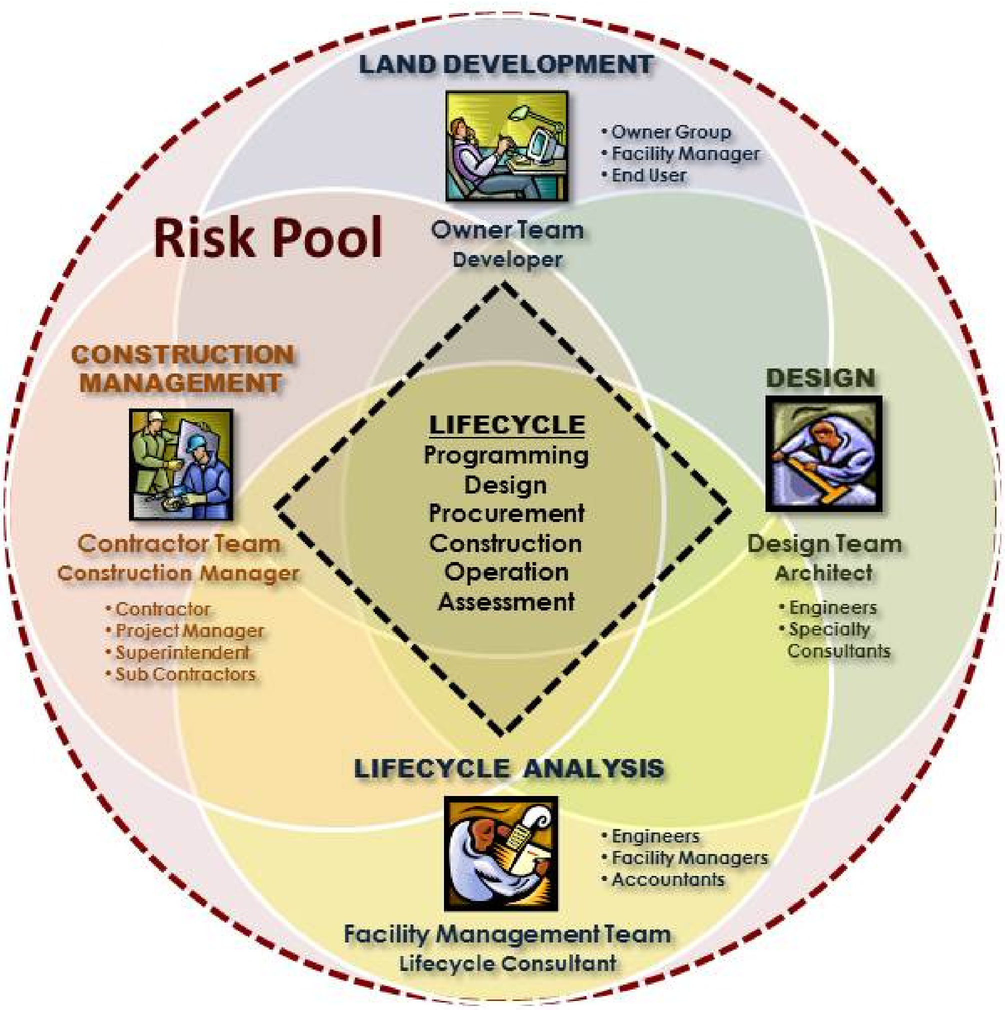


Figure 36. Project Delivery Method: Integrated Project Lifecycle (IPL) (Daniels, 2012).

Although lifecycle costs analysts are currently utilized to asses a design's anticipated performance, the consultants that perform these studies are typically retained by either the A&E team or the contractor – a situation which creates an inherent conflict of interest. Analysts retained as "sub-consultants" are motivated by payment for services rendered and the potential of future work, and as such are placed in a situation in which their interest are more closely aligned with the interest of the design and build team, than that of the owner. In order for the lifecycle analyst to perform their fiduciary duties to the owner, an independent contract must exist directly with the owner such that design and construction techniques can be objectively vetted without concern of contractual repercussions (Figure 37).

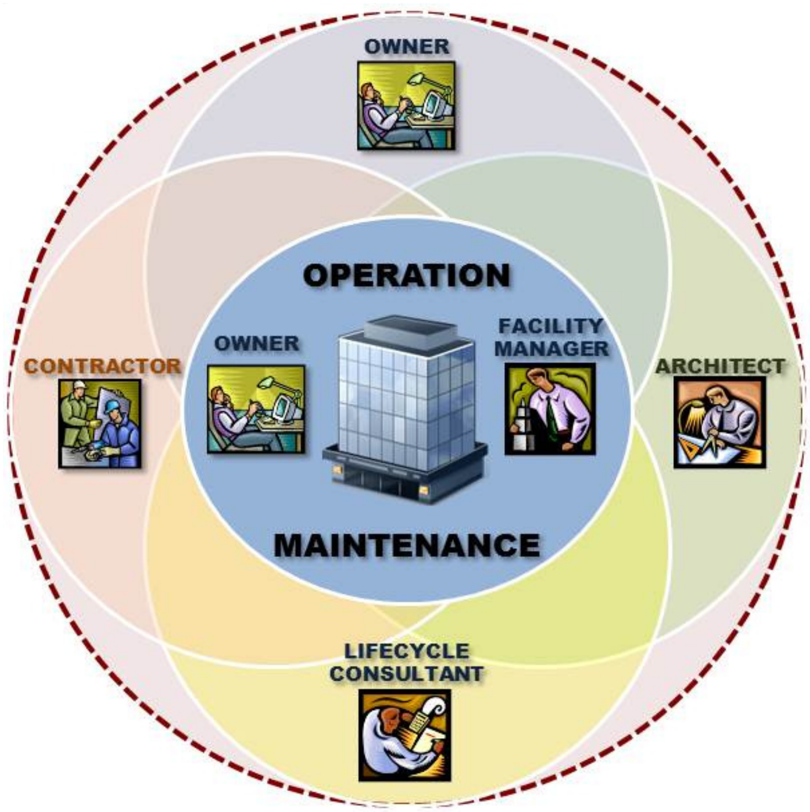


Figure 37. Project accountability: Integrated Project Lifecycle (IPL) (Daniels, 2012).

Furthermore, in order to leverage the time and cost benefits illustrated in the MacLearny curve early information can positively impact project outcomes, whereas waiting to retain the lifecycle analyst until after the retention of the A&E team and the development of a design, has already placed the lifecycle analysis in a position of disadvantage. The following bullets describe the method by which IPL serves to align owner and design build team interests by emphasizing lifecycle costs.

- IPL creates a contractual interest on the part of the design and build team to consider lifecycle operational and maintenance costs to the owner - beyond project delivery.
- Financial rewards for the design and build teams are disassociated from lowest startup cost and realigned with the owners long term financial objectives for the building project.
- The lifecycle consultant provides early preconstruction feedback to all lifecycle cost and value engineering decisions.
- Design and build teams are paid shared reward dividends based on the ongoing exemplary performance of the building project.
- Design and build teams are incentivized to monitor and maintain building performance post project completion to assure continuing dividend returns.
- The advantages of IPL can only be realized by owner operators (entities with a vested financial interest in reducing their building’s operational expenses).
- IPL requires a sophisticated owner group with the authority to provide binding direction to the design and build team.

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APPENDIX 1: LEED PROJECT CHECKLIST (USGBC,2009)

LEED for New Construction v2009

Registered Project Checklist

Project Name

Date

Y	N	?	Sustainable Sites		Possible Points: 26
Y			Prereq 1	Construction Activity Pollution Prevention	
			Credit 1	Site Selection	1
			Credit 2	Development Density and Community Connectivity	5
			Credit 3	Brownfield Redevelopment	1
			Credit 4.1	Alternative Transportation—Public Transportation Access	6
			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Roon	1
			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Ve	3
			Credit 4.4	Alternative Transportation—Parking Capacity	2
			Credit 5.1	Site Development—Protect or Restore Habitat	1
			Credit 5.2	Site Development—Maximize Open Space	1
			Credit 6.1	Stormwater Design—Quantity Control	1
			Credit 6.2	Stormwater Design—Quality Control	1
			Credit 7.1	Heat Island Effect—Non-roof	1
			Credit 7.2	Heat Island Effect—Roof	1
			Credit 8	Light Pollution Reduction	1

Y	N	?	Water Efficiency		Possible Points: 10
Y			Prereq 1	Water Use Reduction—20% Reduction	
			Credit 1	Water Efficient Landscaping	2 to 4
			Credit 2	Innovative Wastewater Technologies	2
			Credit 3	Water Use Reduction	2 to 4

Y	N	?	Energy and Atmosphere		Possible Points: 35
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
			Credit 1	Optimize Energy Performance	1 to 19
			Credit 2	On-Site Renewable Energy	1 to 7
			Credit 3	Enhanced Commissioning	2
			Credit 4	Enhanced Refrigerant Management	2
			Credit 5	Measurement and Verification	3
			Credit 6	Green Power	2

Y	N	?	Materials and Resources		Possible Points: 14
Y			Prereq 1	Storage and Collection of Recyclables	
			Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
			Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Element	1
			Credit 2	Construction Waste Management	1 to 2
			Credit 3	Materials Reuse	1 to 2

Y	N	?	Materials and Resources, Continued		
			Credit 4	Recycled Content	1 to 2
			Credit 5	Regional Materials	1 to 2
			Credit 6	Rapidly Renewable Materials	1
			Credit 7	Certified Wood	1

Y	N	?	Indoor Environmental Quality		Possible Points: 15
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
			Credit 1	Outdoor Air Delivery Monitoring	1
			Credit 2	Increased Ventilation	1
			Credit 3.1	Construction IAQ Management Plan—During Construction	1
			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
			Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
			Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
			Credit 4.3	Low-Emitting Materials—Flooring Systems	1
			Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Product	1
			Credit 5	Indoor Chemical and Pollutant Source Control	1
			Credit 6.1	Controllability of Systems—Lighting	1
			Credit 6.2	Controllability of Systems—Thermal Comfort	1
			Credit 7.1	Thermal Comfort—Design	1
			Credit 7.2	Thermal Comfort—Verification	1
			Credit 8.1	Daylight and Views—Daylight	1
			Credit 8.2	Daylight and Views—Views	1

Y	N	?	Innovation and Design Process		Possible Points: 6
			Credit 1.1	Innovation in Design: Specific Title	1
			Credit 1.2	Innovation in Design: Specific Title	1
			Credit 1.3	Innovation in Design: Specific Title	1
			Credit 1.4	Innovation in Design: Specific Title	1
			Credit 1.5	Innovation in Design: Specific Title	1
			Credit 2	LEED Accredited Professional	1

Y	N	?	Regional Priority Credits		Possible Points: 4
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1

Y	N	?	Total		Possible Points: 110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

APPENDIX 2: BURNHAM BOILERS

Highlights

- Low or High Pressure Steam or Water
- Highly Efficient Three-Pass Design
- Fully Waterbacked Primary Heating Surfaces
- Separate Rear Tube Sheets for Longer Service Life
- Wetback Design Allows Easy Front and Rear Access
- Made in the USA
- No Expensive Refractory or Door Replacement as with Some Drybacks

Benefits

- Forced-Draft Firing with Oil (No. 2,4,5, or 6), Gas, or Combination Gas/Oil
- Low or High Pressure Steam or Water
- High Efficiency Three-Pass Design
- Fully Water-Backed Primary Heating Surfaces for Increased Efficiency
- Separate Rear-Tube Sheets for Longer Service Life
- Easy Front and Rear Access for Ease of Maintenance
- ASME Code Construction

Series 3

The Burnham Commercial Wetback Packaged Boiler can save you thousands of dollars over the life of your boiler. Our quality engineering takes maximum advantage of long-term energy and maintenance efficiencies. Unless you take those efficiencies into consideration along with price when you choose a boiler, you can be in for enormous hidden costs.

The Series 3 matches burner to boiler, providing a fuel efficient low-maintenance package. It takes maximum advantage of long-term energy and maintenance efficiencies.

Boiler Cost is Not Just a First-Year Proposition.

Long after the installation is paid for, fuel, maintenance, and repair costs continue and can increase over the years. Burnham Commercial Packaged Boilers are designed to minimize these significant, ongoing ownership costs.

That's Burnham Commercial's High Life-Cycle Efficiency!

While most competitive boilers can give fuel-to-steam efficiencies of 80% or over when they are new — how consistently can they be expected to maintain this level? Burnham Commercial wetback boiler performance will not drop due to deteriorating rear refractory, leaking door baffles and seals, and heat-stressed rear tube sheet as can happen with some drybacks: the fact is that easy access is a necessity for those with heavy refractory, as they need frequent, expert maintenance.

DOWNLOADS

The Burnham Commercial Wetback Saves Money on Maintenance.

Over the life of a dryback, brittle refractory baffling and rear door gasketing will require continual monitoring, maintenance, and replacement, costing thousands upon thousands of dollars. These built-in maintenance coats can eventually equal or exceed the original cost of the boiler as refractory deteriorates, leaking hot gas causes boiler efficiency to fall until the condition is noticed and repairs can be made (expensive flue temperature alarms are offered with some drybacks to monitor this dangerous and costly potentiality). The rear door itself can become heat-distorted, requiring an expensive replacement. In addition, boiler downtime during repairs can mean crippling losses.

Highlights

- Four-Pass Full Wetback Firetube Design
- Forced-Draft Firing with Oil (No. 2,4,5 or 6), Gas or Combination Gas/Oil
- Produces a Higher Efficiency Due to the Larger Furnace and Higher Heat Transfer Design

Benefits

- Forced-Draft Firing With Oil, Gas or Combination Gas/Oil
- Low- or High- Pressure Steam or Water
- High Efficiency 4-Pass Design
- Completely Packaged For "Same-Day" Installation
- Heavy Steel Base Provides Adequate Stability Along with Shipping and Rigging Protection
- Front and Rear Full-Sized Hinged Access Doors Are Standard and Secured with Non-Corrosive Brass Nuts
- Access Door is Constructed of Durable, Lightweight Vacuum Formed Ceramic Fiber Making the Door Liner Weigh Less Than 5 Pounds
- Handhole Clean-Outs Are Placed for Ease of Servicing
- UL Approved Packaged Burners Are Trimmed and Wired to Assembled Gas Trains
- 5 sq.ft./hp Rated Design, No Turbulators or Welded Tube-Ends
- 4 Pass Wetback Scotch Boiler—to Learn More About Wetback Versus Dryback, Refer to Our Wetback Literature
- Multitude of QC Checkpoints and Stringent Final Inspection Assures You of a Quality Product
- No Proprietary Parts or Gaskets on the Boiler Trim or the Burner
- Designed for Low Volumetric Release Rates of No More Than 130,000 btu/hr/cu.ft.
- Fiberglass Insulated Aluminized Steel Jacket Is Finish Painted with High Gloss Burnham Blue Enamel
- All External Trim Piping is Designed and Installed In Accordance with the ASME Code and Certified by an Independent Inspection Agency for Compliance

Series 4S 4-Pass

The Series 4S uses the very latest design techniques and standards. This means it is designed for low volumetric release rates and produces a higher efficiency due to the larger furnace and higher heat transfer design. The 4S is also a great option for Low NOx applications.

America's Boiler Company

The Burnham Commercial Series 4S four-pass wetback scotch boiler was designed using our extensive boiler experience and is sold and serviced through the largest and most experienced network of sales representatives in the country. With a complete commercial product offering and unmatched sales and technical support, it's no wonder why we are America's Boiler Company!

Why Choose the Series 4S?

- The design incorporates positive water flow circulation and maximum heat transfer to maximize ratings.
- The handhole clean-outs are placed for ease of servicing.
- The access door is constructed of durable, lightweight vacuum formed ceramic fiber - the door liner weighs less than 5 pounds!
- All external trim piping is designed and installed in accordance with the ASME Code and is certified by an independent inspection agency for compliance.
- The fiberglass insulated steel jacket is finish painted with high gloss blue enamel.
- The front and rear full-sized hinged access doors are standard and secured with non-corrosive brass nuts.

DOWNLOADS

Highlights & Benefits

Our proven designs use the very latest Low NOx techniques and standards, and every Burnham Commercial Low NOx package design application is approved by our Engineering Department and our burner vendors' Engineering and applications Design Groups. Our successful track record, assures you that our products, and our burner selection, are the best available. Being America's Boiler Company, we know what burner vendors are looking for in boiler designs when it comes to reduced NOx combustion levels:

- Large Furnaces for Low Volumetric Release Rates
- High Heat Transfer for the Most Efficient Boiler for Your Application
- Forced-Draft
- Top or Rear Flue Outlet
- Less Burner Motor Horsepower So Less Energy is Used to Operate Your Boiler

Combining these three features contributes to an ideal Low NOx package application.

Low NOx Boiler

America's Boiler Company

Burnham Commercial has extensive experience designing and producing boilers, and we sell and service through the largest and most experienced network of sales representatives in the country. Our representatives are capable of providing technical assistance, competent pricing, start-up and long-term servicing. It's no wonder we are America's Boiler Company!

DOWNLOADS

Low NOx Needs

Being America's Boiler Company, we know what burner vendors are looking for in boiler designs when it comes to reduced NOx combustion levels—large furnaces, high heat transfer, and low draft losses:

- Large furnaces mean low volumetric release rates.
- High heat transfer for the most efficient boiler for your application.
- Less burner motor horsepower so less energy is used to operate your boiler.

Combining these three features contributes to an ideal Low NOx package application.

Our firebox design provides the largest furnace possible in a firetube, and our scotch boilers have some of the largest furnaces available in our market - meaning we can meet all your Low NOx needs.

Important Design Considerations

Our proven designs use the very latest Low NOx techniques and standards. Our furnace, the workhorse of the boiler, is designed for low volumetric heat release. The lower the release rates, the "easier" your boiler works. As your boiler works easier, less stress is put upon the steel, tube ends, refractory, etc., resulting in a longer lasting boiler. In addition to longevity, a larger boiler makes for ease in firing using any selected burner vendor. Smaller furnaces are extremely susceptible to erratic flame patterns. Deformed flame patterns cause uneven heat distribution, uneven absorption and localized hot spots, which can lead to overheating and over stressing. Our selections give the customer the choice of any of the major Low NOx burner manufacturers. Because we have so many proven product design selections to choose from, we can custom fit any of our products to your boiler room. Burnham Commercial can offer you firebox, three-pass or four-pass wetback scotch. We are the only manufacturer who can offer our packages complete with flue gas recirculation piping, when necessary. That eliminates extra design responsibility and field installation costs.

APPENDIX 3: CARRIER CHILLERS

30XA AQUAFORCE®

Outdoor, Air-Cooled Liquid Chiller
with R-134a Refrigerant

80 to 500 Nominal Tons

AquaForce 30XA chillers were designed from the ground up to meet the efficiency demands of today and the future by providing premium air-cooled chiller packages for contractors, consulting engineers and building owners. Value-added features include rotary screw compression, R-134a HFC refrigerant, a quiet AeroAcoustic™ fan system, easy to use ComfortLink™ controls, microchannel condenser coil technology, and an optional integrated hydronic pump package with or without VFD.

Additional Information

Physical data

Documents/DownLoads

Awards

Dealer Design Awards

Training Classes

Controls

HVAC System Design

Service

Sustainable Design

Video
(requires video player)

Interactive Tour
(requires Flash)

Performance Features

- Full-load EER values up to 10.9
- IPLV values up to 15.4
- ASHRAE 90.1 complaint
- AHRI certified
- Easy to use controls
- Low sound levels
- AeroAcoustic fan system
- Operation from -20 F to 125 F ambient conditions
- High-efficiency screw compressors
- Novation® microchannel heat exchanger (MCHX) condenser coils

19XR EVERGREEN®

High-Efficiency
Hermetic Centrifugal Chiller

19XR
200 to 1,500 Nominal Tons (703 to 5275 kW)

19XRV with Variable frequency Drive
200 to 1,450 Nominal Tons (703 to 5100 kW)

The Evergreen 19XR,XRV centrifugal chillers achieve energy efficiency levels using proven technology designed specifically for chlorine-free refrigerant. This combination ensures the most cost-effective, reliable solution for today's comfort cooling and process cooling applications.

Carrier's Evergreen chillers offer the best value in high-efficiency, chlorine-free centrifugal HVAC chillers.

Performance Features

- IPLV to 0.35 (19XRV)
- Chlorine-free HFC-134a refrigerant
- Hermetic compressor motor
- Low energy consumption during part load and full load operation
- Aerodynamically contoured impeller
- Multilingual display
- Compatible with Carrier Comfort Network® (CCN) communication link

Reliability Features

- ASME constructed heat exchangers
- Single-stage positive-pressure compressor
- Low voltage control circuits
- Lowest industry refrigerant leakage rate at less than 0.1%
- Hermetically sealed compressor, motor, and transmission

Additional Information

Physical data

Documents/DownLoads

Starter Information

Starter Easy Reference

Carrier University Training

Controls

HVAC System Design

Service

Sustainable Design

23XRV EVERGREEN®

High-Efficiency
Variable Speed Screw Chiller

300 to 550 Nominal Tons (1055 to 1934 kW)

The 23XRV chiller is the world's first integrated variable speed, water cooled, screw chiller. The 23XRV incorporates significant breakthroughs in water-cooled chiller technology to provide excellent reliability and achieve superior efficiencies at true operating conditions without compromising the environment. Quality design and construction make the Evergreen 23XRV chillers the best choice for modern, efficient chilled water plants.

Carrier's Evergreen chillers offer the best value in high-efficiency chlorine-free variable speed screw HVAC chillers.

23XRV Video
(Requires Flash)

Interactive Tour
(Requires Flash)

Performance Features

- IPLV to 0.299
- Chlorine-free HFC-134a refrigerant
- Full Load kW/Ton to 0.53
- Tri-rotor, positive displacement screw compressor
- Hermetic compressor motor
- Refrigerant-cooled, unit-mounted variable frequency drive
- Low inrush current
- Operation of up to 0.99 power factor

Additional Information

Physical data

Documents/DownLoads

Carrier University Training

Controls

HVAC System Design

Service

Sustainable Design

VITA

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